METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

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THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

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Speeding Steel Section Production

New Finishing Equipment at the Frodingham Plant of the Appleby-Frodingham Steel Co., Ltd.

Normal, orderly and rational development of the existing plant at the Appleby-Frodingham Steel Works is in progress, and, when completed, production of steel is expected to reach 1,000,000 tons a year. The finishing equipment, which has recently been put into operation, is the latest of its kind in the world, and facilitates handling of a full range of sections and joists from the section mill to transport wagons. Following a visit to these works brief reference is made to these developments.

General view of the Frodingham Blast-furnaces and Steelworks.

SINCE its inception, in 1859, the Frodingham works have been notable for the way in which the plant has been remodelled and kept up to date. In combination with the adjoining Appleby works to form the Appleby-Frodingham Steel Co., Ltd., it is one of the constituent companies of the industrial group known as the United Steel Companies, Ltd. Both plants are equipped with every possible mechanical aid and labour-saving devices to facilitate large output and rapid handling, in order to maintain regularity of product in surface, gauge, and dimensions, to meet the stringent modern demands of the steel user.

Very substantial developments are in progress at these works. The melting plant at Appleby steelworks, which already comprises two 300-ton open-hearth furnaces, three 250-ton furnaces, together with a 500-ton mixer, is to be augmented by two further 300-ton furnaces and a 600-ton mixer. One of the melting furnaces is at present under construction. This is just a normal, orderly, and rational development of the existing plant, and will make the melting shop the largest of its kind in this country. In addition, however, a contract has been placed for a battery of 64 coke ovens with Koppers' Coke Ovens Co., Ltd., which are to supply 6,000 tons of coke per week, and the plant will be complete with full by-product recovery plant.

The Frodingham works is concerned with the production of pig iron and of bars and sections in constructional steel, while the Appleby works produce pig iron, steel plates, and Siemens' open-hearth steel. The steel sections produced comprise the full British Standard range, with many special sections and piling sections, including a full range of joists up to 24 in. × 7½ in. are rolled. To facilitate the handling of this class of work, a new finishing bank has recently been put into operation, which, in the words of Mr. C. J. Walsh, the general manager, is something that has never been done before in this country and which has no equivalent in any part of the world. It is the latest type of finishing bank, and the very last word in the handling of sections and joists of all types and all kinds that the mill can and does produce.

NEW FINISHING PLANT

This new finishing plant deals with the products of the 30-in. section mills, and comprises a travelling bar stopper ; a mechanical cooling bank, complete with approach rack, turn-up and turn-down gear and delivery rack ; roller-straightening machines ; cold bank ; and overhead travelling crane and loading roads. In view of the outstanding character of the devices incorporated in this finishing bank, a detailed description will be of interest :—

Travelling Bar Stopper

The steel sections, after leaving the section mills, are carried by roller racks to a modernised hot saw capable of cutting the largest sections at a cutting speed of 1 ft. per second. Just beyond the saw, and running on bridge rails, is the new travelling bar stopper, that on the near side being supported by a cast-steel beam to which is fitted a toothed rack with vertical teeth. The main frame is of cast steel, and is carried on cast-steel wheels, the drive being supplied by a 25 h.p. reversible motor giving a travelling speed of 300 ft. per min. By means of an electrically operated change-gear, however, the speed can be instantly changed to 60 ft. per min. for fine adjustments. Roller bearings are used where possible, the remaining bearings being of split bronze with removable caps. The range is from 16 ft. to 75 ft., and the operator controls

The cooling bank forming part of the new finishing equipment.

his position from a scale, marked in feet and inches, attached to the roller train.

Behind the hot saw and leading to the mechanical bank is a roller train, about 250 ft. long, consisting of 33 individually driven electric rollers. The rollers are driven directly by low-frequency motors and carried in roller bearings on a rigid sectional steel framework; they have a peripheral speed of 500 ft. per min. Below the floor plates in this roller train are mounted nine stoppers, which are lifted into position by electrically operated thrusters. The sawn bars are pushed from the roller train by fingers which are ambushed on the return to clear on-coming bars, each finger being controlled by its own solenoid. At this stage joists and channels are turned up on their flanges by turn-up elements arranged opposite each section of the cooling bank. Other sections, such as angles and flats, are left in the as-rolled position. There are six sections of turn-up elements arranged in three pairs, each pair being driven by a 25 h.p. motor. A series of clutches operated by electric thrusters enables Section I or Section II to be driven alone or together, and so on for succeeding sections. A second movement of the push-off gear removes the turned-up bar to the main conveying system at the same time as the following bar is being positioned over the turn-up gear. The time cycle is five seconds.

The finishing bank and equipment, which in many respects is unique and original in design.

Mechanical Cooling Bank

The cooling bank is in six sections, the first being 64 ft. long, two or three 24 ft. long, and each of the remaining three 44 ft. long. Each section can be driven alone or the following combinations can be made, again by clutches operated by electric thrusters—1 and 2, 2 and 3, 3 and 4, 5 and 6.

Three drives, each by an 80 h.p. motor, are so arranged that Sections I and II are from one motor and III and IV, and V and VI from the other two. Gear boxes enable either a 5-second or a 10-second cycle to be used. As the bars are equally spaced, one in each line of fingers, and an adequate depth provided beneath the bank, very rapid and almost perfect natural-air cooling takes place.

On the outgoing side of the cooling bank a turn-down gear, similar to the turn-up gear on the ingoing side, brings the joists and channels into the right position for entering the roller-straightening machines. The bars are pushed on to a delivery train of 30 rollers, similar to those in the saw roller train, by the fingers of the main conveyer, and as the roller straighteners are at the end of this train, the latter becomes the feeding medium for the machines.

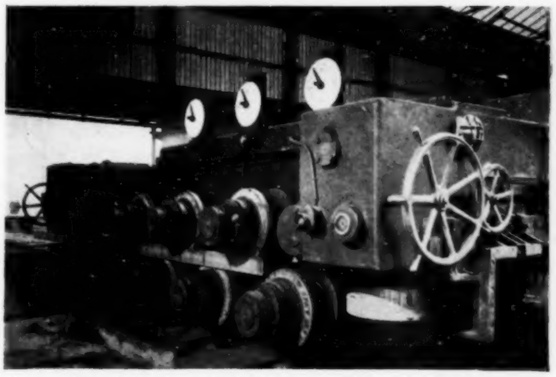
One man, in a control box on the ingoing side, controls the saw roller train, under-floor stoppers, push-off gear, turn-up gear, and main conveyer, and when a section of the bank is full, he switches over the control to a man on the delivery side, who then controls the main conveyer, turn-down gear, and the roller train feeding the straightening machines. Immediately in front of these machines and under the roller train, is a travelling bar lifter which can be raised under a series of openings in the floor plates to assist cambered bars, such as angles, into the machines. The lifter can only be raised when immediately below an opening, its position being shown by an illuminated tell-tale.

Roller Straighteners

There are two roller straighteners, separated by a by-pass roller rack mounted on a travelling platform, so that either the small or the large machine or the by-pass can be brought into line with the delivery train from the cooling bank. Both machines are of the overhung, seven-roller type, and between them cover the full range of sections rolled. They are both in a covered building, in one end of which is the stock of rollers, sleeves, etc., and the mandrils for correctly pre-assembling the rollers. The whole building is served by an 8-ton overhead crane, and roller-changing takes no more time than is necessary to change rolls in the mill.

Cold Bank

The bars are delivered from the straighteners on to a train of 18 rollers, exactly similar to those in the saw train. Three under-floor stoppers are placed in the train to serve three sections of the cold bank on each side, the arrangement being two sections at 60 ft., two at 20 ft., and two at 40 ft. The bars are pushed from the train to the skids by fingers which can be ambushed on the return stroke. Each stopper has its own thruster, and each finger its own solenoid as on the cooling bank.



The smaller of the two straightening machines for steel sections.

Rolling mill for steel sections at Frodingham works.

Crane and Loading Roads

Over the cold bank, with its track at right angles to the travel of the bars up to this point, is a 7½-ton overhead crane with a span of 130 ft. The main feature of this part of the plant is that stanchions, girders, etc., are of all-welded construction, the only exception being the main girders of the crane itself, which are of high-tensile steel. The crane is of the rigid beam type, and is provided with motor-driven extensions to the beam, to facilitate the handling of long bars.

Under the gantry are side presses for rectifying the small percentage of bent bars coming from the roller straighteners, cold saw, and loading roads. The latter pass right through the gantry to give extra wagon space, and are suitably inclined so that no locomotive is required to let down the wagons from the far end, and also to enable fly-shunting to be used. The whole finishing plant is so arranged that specifications on which there are no delivery restrictions are actually straightened, and on wagons within an hour or two of rolling.

THE FRODINGHAM PLANT

The Frodingham blast-furnaces comprise four furnaces. Nos. 1 and 4 are modern, and are mechanically charged, the former with an average output of 1,650 tons per week, and the latter 2,000 tons per week. Nos. 2 and 3 are older type furnaces, but with modern hearths and closed tops, and are hand-charged, each having an average output of 1,000 tons per week. To appreciate these capacities, it should be realised that the local ironstone, which is smelted, is relatively low in iron content, an average analysis at one face giving 23% of iron, though the composition varies considerably, both in the different strata of the deposit and according to its position in the district.

Melting Shop

In the Frodingham melting shop are four tilting furnaces, varying in capacity from 130 to 175 tons each; they are served by a mixer of 400 tons capacity, with a ground type charger, and heated by blast-furnace gas. Casting is done on cars by three 80-ton overhead cranes. The cars with the moulds and ingots are shunted into the stripping and soaking pit bay, which has two electric overhead stripping cranes, each with a stripping force of 150 tons. The ingots are here stripped, the empty moulds being placed upon prepared cars for refilling.

The stripped ingots are charged into the soaking pits, of which there are four, each with a capacity of 75 tons, fired by blast-furnace gas. Ingots are drawn from the soakers, and deposited direct on to a rack leading to the cogging mill.

Rolling Mills

The large section mill at Frodingham comprises a 36-in. cogging mill, a 32-in. finishing mill of three stands, and a 15-in. merchant mill with four stands. The cogging mill is of the two-high reversible type, having rolls 36 in. in diameter and 7 ft. 6 in. long, with hydraulic balancing gear and electric screw-down gear. The manipulators are hydraulically operated, and a separate hydraulic accumulator is included in the balancing system. The blooms for the finishing mill are passed through a reheating furnace, constructed to take blooms up to 18 ft. 6 in. long, and fired by blast-furnace gas.

The finishing mill, which is also of the two-high reversible type, is in line with the cogging mill. It has rolls 6 ft. long in the first roughing stand, and 7 ft. 3 in. long in both the second roughing stand and the finishing stand. Both roughing housings are fitted with electrical screw-down gear and automatic forced lubrication for the roll necks and chocks. The mill floor is level with the roller racks, and the blooms are skidded across between the stands by motor-driven skids.

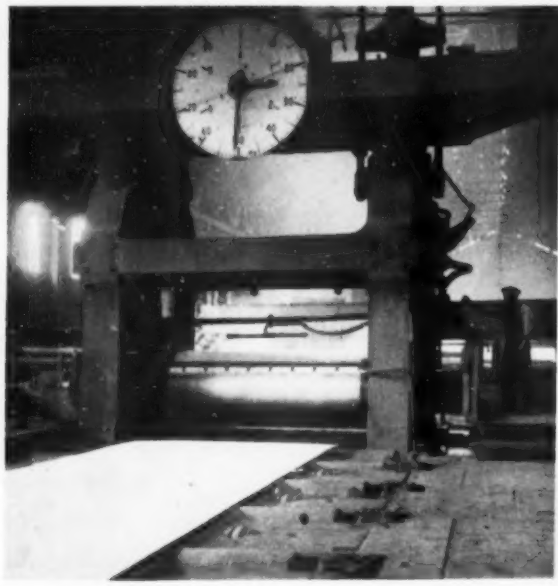
The process of rolling the range of standard joists is as follows: The ingot is rolled down and shaped in the cogging mill. The ends are sheared and the shaped bloom is placed in a reheating furnace. It is withdrawn from this furnace at a suitable temperature and finished to size in the finishing mill. Throughout its working, therefore, the steel is kept at the right temperature to produce, ultimately, a finished product of high-class quality and shape.

THE APPLEBY PLANT

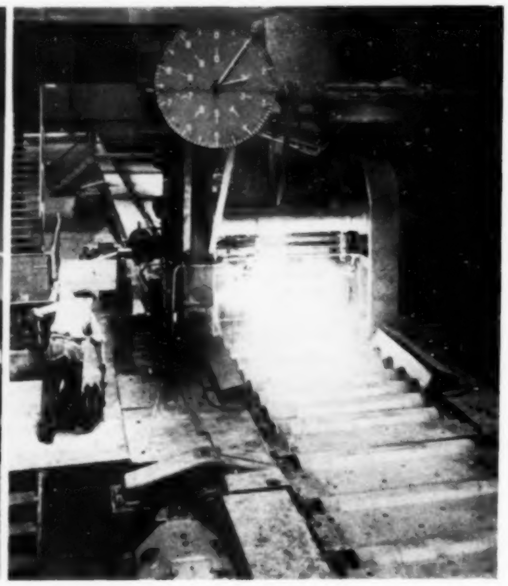
As previously mentioned, the Appleby works are concerned primarily with the production of steel plates and semi-finished steel in the form of slabs and blooms, and in this article it will be of interest to give brief particulars of the plant installed in these works. This plant also comprises four blast furnaces, two of modern design, each with a capacity exceeding 2,300 tons per week, the other two being hand-charged type furnaces, each having a capacity of 1,700 tons per week.

The process of steel-making is carried on in large tilting furnaces fed from a semi-active mixer of 500 tons capacity, which is usually heated by blast-furnace gas. There are five steel furnaces, three of 250 tons capacity, and two of

The test house, showing equipment for physical and mechanical tests on finished material.



The finishing stand of the 10 ft. plate mill at Appleby works.



The finishing stand of the 7 ft. plate mill at Appleby Works.

300 tons capacity. The whole of the mechanism of one 300-tons furnace, including the tilting gear and gas and air reversing valves, is entirely electrically operated. The furnaces are charged by two 50-ton overhead cranes, with 15-ton auxiliary hoists, and three 4-ton revolving ground-type chargers. Each furnace averages 2,000 tons of steel per week from the 250-ton furnaces, and 2,200 tons from the 300-ton furnaces, although amounts considerably in excess of these are frequently made. On completion, the steel is normally tapped into three ladles, with capacities ranging from 75 to 85 tons each. These are transported to the casting stages, where the steel is teemed into the ingot moulds set upon cars. The ingots, which may vary in size from 3 to 23 tons each, are sent to the stripping shed when cool, where the moulds are stripped.

Rolling Mills

The Appleby mills comprise a slabbing mill and 10 ft. and 7 ft. plate mills. The slabbing mill is an electrically driven two-high reversing mill, with forged steel rolls 42 in. in diameter and 9 ft. 6 in. long. The mill is driven through machine-cut helical pinions, and spindles having universal coupling boxes, by a motor capable of exerting a torque of 20,000,000 in.-lb. up to 48 r.p.m., and with a rating of 15,200 h.p. from 48 r.p.m., to 100 r.p.m. A separate hydraulic accumulator is provided in a closed circuit with the balancing cylinder. All the motions of the manipulators on each side of the mill rolls are electrical. Slab shears are capable of shearing up to 54 in. by 18 in., and are operated by a steam hydraulic intensifier, the steam being taken from the waste-heat boilers at the open-hearth furnaces. Beyond the slab shears, hydraulic pushers are installed for dealing with crop ends, and with slabs to be stocked. The scale from the mill is washed by water down an inclined duct into a large catch-pit, and afterwards loaded up by a grab suspended from a 5-ton overhead crane. The slab shear bay is served by a 20-ton overhead crane which loads up the crop ends and handles slabs to and from stock. The run-out rack from the slab shear is continued through into the reheating furnace bay, where there are two reheating furnaces of the soaking pit type with sliding roof doors, and two horizontal-type furnaces. The reheating furnaces are fired by blast-furnace gas, which at this point is maintained at a constant pressure of 0·90in. water gauge, by means of an automatic pressure regulating valve. The horizontal furnaces have automatic draught control and flat roofs of suspended arch type.

The 10-ft. mill has two stands with soft rolls of forged steel, 42 in. in diameter and 12 ft. long, and hard rolls 42 in. in diameter and 10 ft. long. It is a two-high reversing mill, driven by a reversing motor which is a duplicate of the slabbing mill motor. The top hard roll is driven from the bottom roll by a light gearing, to enable the top roll to be balanced by a hydraulic cylinder. A turnover gear for the slabs is provided between the two stands. On the front of the roughing stand a hydraulic slab-turning stool is fitted. Both stands are provided with hydraulic centering arms on each side of the rolls. The rolled plates are passed through a plate mangle on the receiving side of the cooling bank. The mangle has nine rolls, 18 in. in diameter by 12 ft. 6 in. long, and is of specially massive design. The cooling bank is 115 ft. long and 95 ft. wide, and has two sets of chain conveyer type skids, each set being divided into three sections. The skids are so arranged that all the plates on one or more sections are moved towards the delivery rack at one operation. Inserted between these skids are two hydraulic turn-over gears for plate inspection. A further cooling bank unit 57 ft. 6 in. long and 95 ft. wide of similar construction to the larger bank, but in addition being reversible, forms a connecting link between the shearing bay and the finishing department; this bank has turnover gear capable of turning the heaviest plate or slab rolled, for final surface inspection.

The 7-ft. mill is a one-stand two-high reversing mill, with hard rolls 36 in. in diameter, and 7 ft. long. The rolls are driven by a reversing motor, capable of exerting a maximum torque of 14,000,000 in.-lb. up to 60 r.p.m., with a maximum rating of 13,500 h.p. from 60 r.p.m. to 120 r.p.m. The slabs are fed on to the receiving rack by chariot from the reheating furnace bay. On each side of the rolls are fitted hydraulically operated centring arms. The rolled plate is passed through a plate mangle having nine rollers 14 in. in diameter and 7 ft. 6 in. long. The plates are then passed over either of two sections of the cooling bank by ordinary rope-driven skids on to a parallel rack, then back over a third section of cooling bank on to the original rack and so on to the shears. Each section of the cooling bank is 60 ft. long and 47 ft. wide. Built into the third section is a plate turn-over gear.

The shearing equipment serving each of these mills is of similar type and consists of two side-cutting electrically operated, and one cross-cutting hydraulically operated shears. In front of each side-cutting shears are two magnet plate-handling machines of original design, developed by

(*Continued on page* 150.)

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HEAT-TREATMENT

Generalisations and the Component

ADVANCES in the development and use of ferrous and non-ferrous alloys have increased the scope of heat-treatment which to-day has such an important bearing upon almost every finished metal product. The various operations involved in modern heat-treatment require knowledge, skill, and judgment of a high order, and despite progress in heat-treatment plant and equipment, these requirements are probably of greater importance to-day than in the past because of the wider range of materials to be treated and the narrow limits of modern specifications. Modern heat-treatment, therefore, may still be regarded as an art.

It is well known that the specification for a heat-treatable material gives the heat-treatment operations to obtain the properties desired in a given size of test-piece, but this does not take into account problems encountered in the heat-treatment of a particular component. Obviously, unless the results obtained in the heat-treatment shop compare favourably with the standard set in the laboratory, the value of the work is lessened. It is important, therefore, that the application of heat-treatment principles should be given proper consideration in order to ensure a better understanding of the factors governing commercial practice.

On this subject we have received a communication from a well-known heat-treatment authority, and in view of the importance of the subject, we present the opinion of our correspondent on this page.

The Editor, METALLURGIA.

Sir,—It is generally appreciated that heat-treatment has a growing influence upon the quality and cost of the raw material used in engineering production, and that many variable factors affect the conduct of heat-treatment operations. In technical articles on this important subject, however, I wish to make a plea for the component as a component, rather than the more familiar and quite admirable material generalisations and tabulations, based though they may be on production experience. In the course of time the heat-treatment technique for any particular material becomes public knowledge, and providing that the persons in charge of such treatment have adequate ability and facilities, the material as material may not be unduly troublesome—that is, of course, if it is supplied or made to a rigid specification, and if all the implications of its composition and methods of manufacture are fully understood and controllable. But every practical metallurgist has known what it is to sweat blood over the production corpses of a particular component.

It may be that such a component was born out of dimensional necessity, and in consequence was metallurgically cursed from birth. Thin sections and thick may continually seek a divorce, and both dispute the custody of an official test-piece. And most scientific and highly official exceptions may have to be authorised to canonise an irregular treatment which happens to do the job. For heat-treatment has many potential variables—composition and physical condition of material, design of component affecting heating-up and rapid cooling ; methods of heating and cooling, and their possible limitations ; and the specification for the component and/or test-piece. It is quite appreciated that the troubles found by one method may be entirely absent in the experience of another observer, but if they have been successfully overcome they are of practical interest, and should be of great use to young metallurgists if they are placed on record in the technical press.

It would not be sufficient, of course, to make the bare statement that light alloy casting X Y Z gave the best results when quenched from solution treatment in a 20-to-1 soluble-oil emulsion. That would be a creed or dogma ; what is required is that some kindly disposed author shall tell us what happened when he quenched in hot water or oil. Or the more human explanation, why, if a salt bath is used as a heating medium for rather porous light alloy castings, there is not quite the same lack of urgency in curing the porosity as when a dry furnace is used. And dimensional changes !—how various observers find differences on the same component pack-hardened or cyanided ?—or do they find that gear blank consignments from A firm open out more than those from B firm, although both are to the same specification ? And, this being so, " What about it ? " Or even those episodes, where much high theory and oil immersion gazing blinded us to the obvious under our very noses.

The writer has a few such skeletons in his cupboard, which time, the great healer, has kindly clothed in benevolent and humorous reminiscence.

Heat-treatment for strength properties ! This, in all common sense, indicates a component, and a component all too often whose complicated and largely guessed stresses are referred to a series of symmetrical test-pieces—a valuable indication of regularity ! Is this the best we can do ? There is a great lack of published data on the results obtained by testing the component, and the relation of those results to test-pieces. But there are such figures, and they are occasionally very illuminating. The older secrecies and nervous confidences are largely becoming eliminated, and the wise and not too proud metallurgist of to-day has no hesitation in ringing up his friend and saying, " Have you any data on the effect of spheroidal cementite on machining cycle time." And the friend, who has probably suffered from the low-temperature annealing habits of certain suppliers, says so, and in turn mentions a batch of 500 gears which have most unfortunately opened out after carburising and quenching.

These and such are the daily life of the heat-treatment supervisor, and these and such are usually what he wants to talk about, and regrets that he cannot read in the technical press. And he is very proud if he can save the component which was lost, even, as often happens, if he is not quite sure which was the saving grace. So when such occurs, instead of decently burying the episode in the laboratory filing system, why not a little column to METALLURGIA ?—Yours, etc.,

H. T.

March 8, 1937.

[There must be many readers with heat-treatment experiences referred to by our correspondent, which would not only be interesting to other readers, but would be informative and assist in improving knowledge on the subject. We ask these readers to pass on their experiences, and offer the columns of this journal for that purpose. All contributions will be paid for, and if, through lack of time, it is only possible to send the bare facts we will endeavour to present them in a readable form.—EDITOR.]

Aluminium Production in Canada

CANADA is a country exceptionally endowed with broad territories where not only have many of the metals of mankind's use been proved to occur, but where their concentration is in such richness that they can be produced more cheaply than in most competing countries. Such base metals as nickel, copper, zinc and lead are produced from her own ores in enormous quantities. But up till the present no suitable ores have been discovered in Canada for the production of aluminium, yet considerable quantities of this metal are produced and exported, as well as her outstanding production and export of other essential basic metals.

The primary ore of aluminium is bauxite; this ore has not been found in Canada in commercial quantities, and all requirements for the production of primary metal are usually supplied from the United States, which, in turn, imports crude calcined ore from both British and Dutch Guiana, and also maintains a large domestic production. Smaller importations of bauxite are obtained from France and re-exports from Great Britain and Germany; these latter, however, are used in the abrasive and in the chemical trades, and not for the production of primary metal. Some indication of the development of this section of the Canadian metal industry is obtained from the imports of bauxite and exports of metallic aluminium. The imports of aluminium, bauxite, cryolite, etc., during the twelve months ended November, 1936, totalled 336,339,100 lb., valued at $2,935,055, as compared with 253,371,900 lb. in the previous year. During the same period exports of aluminium in bars, blocks, etc., totalled 59,594,000 lb., valued at $11,166,929, as compared with 57,119,800 lb., valued at $9,566,432 a year previously.

Imported ores have previously been subjected to a preliminary treatment; where the ore is to be used for the production of artificial aluminous abrasives, or for the chemical trade, it is merely calcined to remove excess water; where it is used for making fine chemicals, or for the production of aluminium metal, it is first calcined and then treated by a chemical process to produce nearly pure aluminium oxide. The aluminium oxide used in Canada as a source of metal was prepared in the United States from bauxites partly obtained from British Guiana, but last year the Aluminium Company of Canada, Ltd., brought into operation the Arvida plant, at which three electric furnaces are installed for the production of aluminium oxide from calcined ores, and now calcined bauxite is supplied direct from British Guiana. It is noteworthy that a fourth electric furnace is at present under construction at this plant, and will shortly be brought into operation.

The deposits of bauxite in British Guiana are very extensive, and Canada has very close and friendly relations with this Colony. Many of the deposits in favourable locations, according to Harder and Kennedy,* are owned by the Demerara Bauxite Co., Ltd., an associated company of the Aluminium Company of Canada, Ltd., which, with raw materials and manufacturing facilities, provides a self-contained aluminium industry. Bauxite was discovered in British Guiana in 1910, and the first production took place in 1917.

A bauxite beneficiation plant is located at Mackenzie, 65 miles up the Demerara river, and the mines are connected with the plant by a '0-mile narrow-gauge railway. Demerara river is a tidal stream, and is navigated as far as Mackenzie by ocean-going vessels of approximately 3,000 to 3,500 tons. Depending upon the tide, bauxite vessels can be loaded to a draught of 15 ft. to 18 ft. The bauxite deposts occur on both sides of Demerara river for a distance of perhaps 15 miles. They are in the form of more or less flat-lying beds, ranging up to 25 ft. in thickness, and covered by sand and clay overburden from a few feet to 60 ft. or 80 ft. deep.

The bauxite is mined mostly by steam-shovel, and is transported in wagons to Mackenzie, where it is crushed, washed, dried and loaded directly into vessels. The crushing consists in reducing the ore to a size of 2½ in. to 3 in., and under; the washing removes the clayey and silicious impurities, and the drying reduces the free moisture content from an average of 12% in the crude material to about 1% in the ore, as shipped. Several grades of bauxite are produced, depending upon whether the ore is intended for the manufacture of chemicals, refractories, abrasives, or aluminium metal. As shipped the metal-grade bauxite has approximately the following composition: 61·000% Al_2O_3, 2·50% SiO_2, 2·50% Fe_2O_3, 2·25% TiO_2, loss on ignition 31·75%.

It is often overlooked that the aluminium industry has been established in Canada for many years. The construction of an aluminium smelter was started as long ago as 1899 by the Northern Aluminium Co., Ltd., which became the Aluminium Company of Canada, Ltd., in 1925. This was one of the first industries to locate at Shawinigan Falls, Quebec, and the first ingot aluminium was produced two years later. At that time the annual total world production of aluminium was only 9,000 metric tons. It increased slowly until about 1908 when it took a sharp upward turn which, with the exception of a slump during the years immediately following the great war, continued until about 1930, when it reached a peak of 271,100 metric tons.

To cope with the increasing demand the Shawinigan smelter was enlarged from time to time. However, by about 1924 it was evident that very much greater capacity was desirable. The result was that, in 1926, the aluminium smelting plant at Arvida, Quebec, complete with its model town, came into being. In addition to the production of ingot aluminium the fabrication of ingots into useful forms was carried on in Canada as far back as that of aluminium smelting; the Northern Aluminium Co., Ltd. had a wire mill in operation at Shawinigan Falls in 1901, but until 1915 all the aluminium wire and cable produced in Canada was fabricated from imported aluminium rod; since the construction then of a rolling mill for rolling rod from aluminium wire bar, all the operations for the production of aluminium wire and cable from the ingot have been performed in Canada at Shawinigan Falls, and to-day this plant ranks among the most up to date of its kind in existence.

Although the only company in Canada producing virgin metal, the Aluminium Company of Canada, Ltd., is by no means alone in the aluminium-fabricating field. There are about a dozen other factories which fabricate aluminium as their main line of activity. There are also a number of important manufacturing concerns that manufacture aluminium products together with products of other metals, such as wire and cable, foil, powder and castings. Canada's capacity for the production of ingot aluminium exceeds 45,000 metric tons per year, but as her industries can only absorb a very small percentage of this total most of her production is exported. A considerable quantity of semi-finished and scrap aluminium is also exported, the semi-finished metal being in the form of plates, sheets, circles, bars, rods, wire cable, foil, hollow-ware and miscellaneous manufactures.

Until a comparatively few years ago practically all the world's markets were open to Canadian aluminium; to-day, due to high tariffs or quotas that are virtually embargoes, many of these markets are now closed. Since the conclusion of the Ottawa agreements, exports of Canadian aluminium—which are an appreciable part of Canada's external trade—are going more and more to countries of the British Empire.

* E. C. Harder and E. V. N. Kennedy Proc. Can. Inst.M.M. 1935. pp. 355-62.

Production in Canada of metals of the platinum groud totalled last year 233,652 fine oz., valued at $7,741,000. Except for a very small quantity of stream platinum produced annually in British Columbia, the source of Canadian platinum group metals are the nickel-copper rose of the Sudbury area.

Inhibited Pickling Solutions in General Finishing Shop Practice

By P. MABB

A number of commercial inhibitors for hydrochloric and sulphuric acid pickling solutions are considered and compared on a practical basis. The work described demonstrates a method for determining the optimum concentration of inhibitor, its efficiency over a range of concentrations, its protective action on the metal pickled, and the consequent saving in acid consumed.

THERE are many subsidiary processes conducted in general engineering that are realised as essential links in the production chain, but which are not always given the same scrutiny and attention in planning and development that are given to the more truly engineering operations involved. It is frequently found that incidental cleaning and acid pickling fall in this category. Where production concerns the manufacture of a miscellany of iron and steel components by machining, pressing, forging, etc., and these subsequently have to be finished by painting or plating, and ultimately assembled together, the need for acid pickling for cleaning may originate in one of many ways. Black stock as the raw material; heat-treatment oxide or scale from annealing or hardening operations; incidental rusting: one or more of these factors may have to be catered for, and, in any case, work for electroplating, however "clean," will have a brief acid treatment prior to entering the plating vats.

The conception of pickling processes in this sphere of engineering, namely, in industries concerned with the handling of miscellaneous small articles, differs fundamentally from pickling operations in the rolling and drawing mills. In this latter case pickling forms a recognised link in production processes, and it is therefore of necessity appreciated and fully controlled to produce the desired end in the most efficient and economic manner. Again, in the case of rolling and drawing mills, pickling is a large-scale job, and one or only a few types of work have to be treated so that there is a constancy in the process which lends itself to precise control. In the treatment of miscellaneous articles, on the other hand, only in a few instances does similarity of types of object, with respect to mass, size and condition, obtain. In general, articles arrive in the pickling shop in uneven flow, varying condition of surface, bright annealing scale, rolling scale, rust, and are pickled with different immediate objects, viz., for plating, for further machining, for storage, etc.; also, the quantity of work to be handled rarely warrants the undivided attention of a single operator, who may have to attend to such other work as degreasing, bright acid dipping, etc. This complex state of affairs has to be legislated for, and it is not surprising therefore to find that often the technical side of the organisation leaves the treatment of this work to the discretion of the practical department concerned. Very good results may be procured by this procedure, but it tends to ignore what developments are made in this field, and does not ensure that most efficient pickling in the sense of most economic, speedy and least damaging to the metal by dissolution or pitting is secured.

Viewed from the practical aspect inhibitors are employed to concentrate the attack of the pickling solution upon the oxides, including both rust and scale, and to nullify as far as possible the dissolution of the clean base metal. The attack on the oxides may be by virtue of direct solution in the acid pickle, or indirectly by slight attack on the base metal, and consequent lifting off of the oxide scale mechanically. In this way irregular distribution and thickness of the oxide contamination can be catered for, and the corrosive attack of the pickle upon the more-exposed areas of base metal mitigated. Just how the inhibitor effects this is a problem for the theorist, and one that has not been fully solved.

At first sight it may not appear that the inclusion of inhibitors in the pickling baths for the class of work in question is warranted, because much of it may not require long-period immersion. But the very fact that a wide variety of work is to be treated, with the possibility that work needing only a few seconds immersion may be given the average time for the whole, or even the maximum period, is evidence of the desirability of their inclusion. The presence of the inhibitor reduces acid consumption to a minimum, even with immersion prolonged for a long period after true pickling is complete. It restricts pitting to that consistent with removal of oxide, and almost entirely eliminates corroding into the pure metal. The first advantageous feature means less labour involved in replenishment, apart from the direct monetary saving on acid consumption. The second means a better appearance to the pickled work, elimination of spoilt threads and unnecessarily reduced dimensions, and facilitates subsequent fabrication processes, whether they be machine, forming or surfacing for a final applied finish.

As the quantities of inhibitor consumed are relatively small, the engineering industries in question can best procure one of the many proprietary products now on the market. Even so, the price per pound may bear little relation to the efficiency of the inhibitor, and some simple method of evaluating the price/efficiency ratio should be applied. In the following a number of commercial inhibitors for hydrochloric and sulphuric acid pickles are considered and compared on a practical basis. The work described demonstrates the *modus operandi* for determining the optimum concentration of inhibitor, its efficiency over a range of concentrations, its protective action on the metal pickled, and the consequent saving in acid consumed.

The tests concerned were all carried out on test-pieces of mild steel, 3 in. × 2 in. × 0·025 in. thick; two varieties of steel were employed, viz.—bright rolled, deep-stamping mild steel as representative of the class of work requiring very little pickling, and a good-quality cold-rolled, close-annealed (CRCA) mild steel representing medium conditions. Duplicate tests were made for each measurement throughout the investigation.

The hydrochloric and sulphuric acid pickles were employed. A 50/50 mixture, by volume of commercial muriatic acid and water, operated cold, was used to represent the former, and a 7% (by weight) solution of commercial sulphuric acid in water, operated at 70° C., typified the latter. No attempt was made to compare the efficiency of different acids at various concentrations as pickling solutions, the intention being solely to study inhibitors. For this reason the two pickles mentioned were selected as representing good commercial pickles, not necessarily the best ones.

Five different inhibiting agents were included in the series, designated in the tabulated data by letters, viz.:

A.—A proprietary solid.
B.—A proprietary solid.
C.—A proprietary solid.
D.—Commercial quinoline (liquid).
E.—A proprietary liquid.

Inhibitor concentrations of nil, 0·5%, 0·10%, 0·50% and 1·0% (of the acid pickling solution) were employed in a

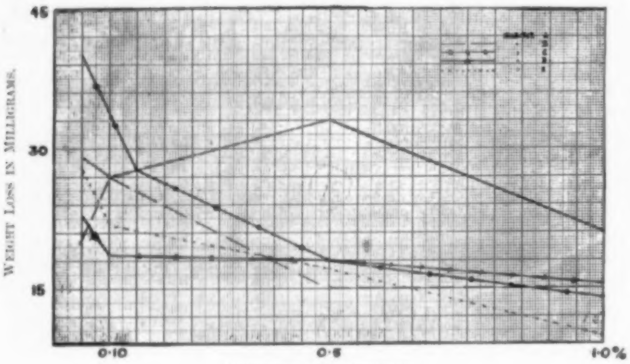


Fig. 1.—Bright mild steel in hydrochloric acid pickle at various inhibitor concentrations.

series of preliminary trials to determine the most economic and efficient quantity of inhibitor required.

Tables I, II, III, and IV give the results of these preliminary experiments, being a record of weight losses of the immersed steel specimens in time intervals of $\frac{1}{4}$, $\frac{3}{4}$ and 17 hours. Table No. 1 is concerned with bright mild steel in hydrochloric acid pickle; No. 2, with CRCA steel in the same acid; No. 3, with bright mild steel in sulphuric acid pickle; and No. 4, with CRCA in the latter. In each table is included a "blank" series, representing the effect of pickling specimens with no inhibitor present. Naturally, some inconsistency from test to test arises, due to the impossibility of securing all specimens of one series in identical surface condition of smoothness, degree of rust or scale, etc., and hardness and superficial strain. The pickling times for complete cleaning varied from a few seconds to minutes for the bright specimens in both acids, and from $\frac{1}{4}$ to $\frac{1}{2}$ hour for the CRCA samples. The first point of note from the tables is the fact that marked inhibition of attack on the base iron does occur; secondly, it is seen that 0·05% of inhibitor is effective, and 0·10% is a good all-round concentration. For greater clarity this is presented graphically in Figs. 1, 2, 3 and 4, the weight-losses on 17 hours being plotted against inhibitor concentration. It is realised that a much larger number of specimens and more concentrations should have been employed to secure more truly representative curves. But this rather brief investigation was carried out to show the general merits of proprietary inhibitors, and would serve to exclude those which showed up to less advantage from a more comprehensive survey. The apparent erratic paths of some of the curves in the circumstances is not therefore unexpected.

In all subsequent experiments, duplicate specimens of the same size and materials, the same two acid pickling solutions, and all inhibitors at concentrations of 0·10% were employed. Weight-losses were recorded on the specimens immersed for periods of $\frac{1}{4}$, $\frac{1}{2}$, 1, $2\frac{1}{2}$, $4\frac{1}{2}$, 24, 48 and 72 hours. These values are recorded in Tables V, VI, VII, and VIII, and shown graphically in Figs. 5, 6, 7 and 8. In both cases No. 5 refers to bright mild steel in cold hydrochloric pickle, No. 6 to CRCA in the same acid, No. 7 to bright mild steel in hot sulphuric acid pickle, and No. 8 to CRCA in this acid. All the inhibitors are good,

TABLE I.

INHIBITIVE EFFICIENCY AT VARIOUS CONCENTRATIONS OF SEVERAL INHIBITORS.

Loss in Weight in Milligrams of Bright Mild Steel Pickled in 50/50 Cold Hydrochloric Acid.

Sample No.	% of Inhibitor.	Inhibitor.														
		A			B			C			D			E		
		Pickling Time in Hours.														
		$\frac{1}{4}$	$\frac{3}{4}$	17	$\frac{1}{4}$	$\frac{3}{4}$	17	$\frac{1}{4}$	$\frac{3}{4}$	17	$\frac{1}{4}$	$\frac{3}{4}$	17	$\frac{1}{4}$	$\frac{3}{4}$	17
1	0	7	16	119	17	29	340	—	—	—	—	—	—	—	—	—
2	0	9	19	112	9	20	319	—	—	—	—	—	—	—	—	—
3	0·05	7	12	34	6	10	22	7	12	24	6	13	35	3	4	20
4	0·05	5	10	25	3	9	19	5	9	22	6	12	44	4	8	36
5	0·10	6	12	32	6	8	26	5	7	18	9	13	27	2	7	17
6	0·10	6	10	22	6	8	29	5	11	20	3	11	30	0	12	27
7	0·50	4	13	36	5	9	14	3	10	17	3	12	18	2	9	18
8	0·50	5	11	30	6	7	16	8	14	19	5	11	18	3	4	15
9	1·0	2	9	22	5	7	13	4	9	13	4	9	14	2	2	9
10	1·0	3	9	21	5	7	17	9	17	18	5	9	14	2	4	11

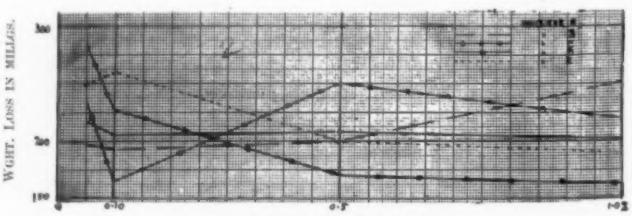


Fig. 2.—CRCA steel in hydrochloric acid pickle at various inhibitor concentrations.

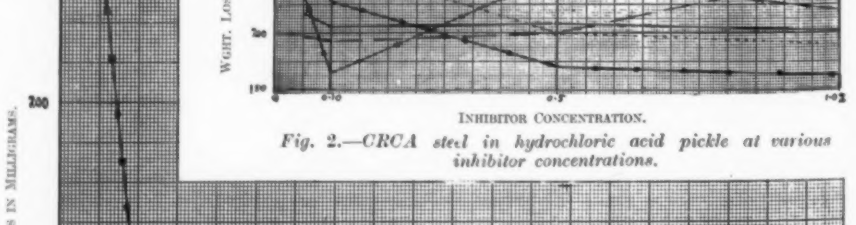


Fig. 3.—Bright mild steel in sulphuric acid pickle at various inhibitor concentrations.

but some better than others. Their behaviour is not the same in both acids, but is independent of the material. Thus, in cold hydrochloric pickle, for both black and bright steel, inhibitor C is the worst, and the others closely follow, the order of merit being D, E, B, A, C. The magnitude of the difference is a little greater in the case of the black steel than the bright material. For the hot sulphuric acid pickles it should be mentioned that in the test-immersion times shown in each 24-hour period, 9 hours was "hot" and 15 hours without the heat maintained. This explains the peculiar course of the curves in the regions from 4 to 24 hours. The order of merit of the inhibitors is revealed as E (best), C, A, D, B. E, C and A are closely the same, with D and B poor in comparison, but nevertheless showing marked advantage over the "blank" with no inhibitor present.

In comparison with commercial acids, inhibitors are relatively costly materials when considered only on the initial price per pound or gallon, as the may be; but the quantity involved per vat is very small. Moreover, inhibitor replenishments under extreme conditions will only be proportional to acid additions, and in the case of heavily rusted or scaled work, which consumes more acid than does brighter material, the inhibitor make-up will be rather less. From the expense viewpoint alone, it must be ensured that the outlay for inhibitor is smaller than the cost-saving on acid consumption. A study of the curves shows that this criterion can readily be achieved. Nos. 5, 6, 7 and 8 particularly demonstrate this point, the advantage being even more marked with hot sulphuric acid pickles than with cold hydrochloric acid solutions. Actual

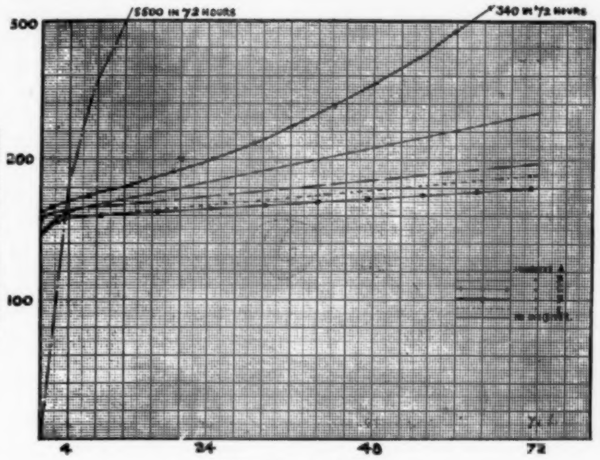


Fig. 6.—CRCA mild steel in hydrochloric acid pickle; various inhibitors at 0·10% concentration.

TABLE II

INHIBITIVE EFFICIENCY AT VARIOUS CONCENTRATIONS OF SEVERAL INHIBITORS.
Loss in Weight in Milligrams of CRCA Steel Pickled in 50/50 Cold Hydrochloric Acid.

Sample No.	% of Inhibitor.	Inhibitor. A			B			C			D			E		
		Pickling Time in Hours.														
		¼	¾	17	¼	¾	17	¼	¾	17	¼	¾	17	¼	¾	17
1	0	183	194	571	231	247	502	—	—	—	—	—	—	—	—	—
2	0	277	286	579	344	361	947	—	—	—	—	—	—	—	—	—
3	0·05	181	184	233	155	161	208	276	284	303	287	292	339	220	221	238
4	0·05	151	155	206	167	175	187	142	147	167	160	160	230	241	247	262
5	0·10	148	151	191	165	173	187	156	163	177	154	157	176	332	336	344
6	0.10	161	163	215	175	184	198	134	139	158	230	234	281	153	157	177
7	0·50	219	221	247	177	189	205	261	265	295	153	156	163	206	209	220
8	0·50	137	138	171	167	183	196	165	172	207	166	171	180	164	168	183
9	1·0	186	189	221	294	304	317	152	159	192	148	151	156	181	185	194
10	1·0	151	157	182	155	166	187	213	222	250	158	164	170	150	153	167

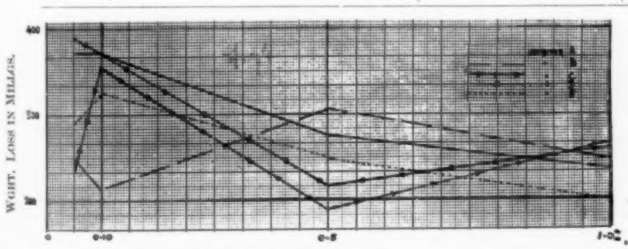
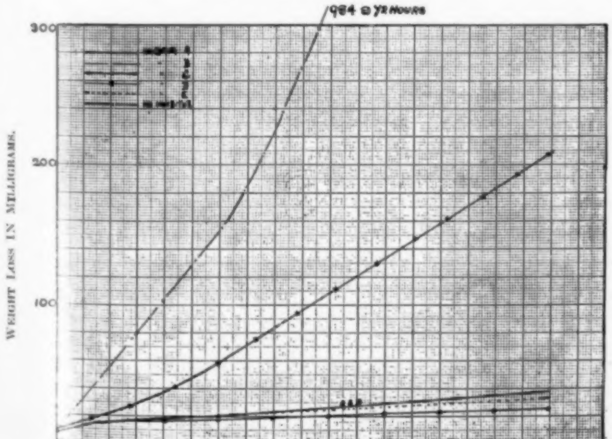


Fig. 4.—CRCA steel in sulphuric acid pickle at various inhibitor concentrations.



F . 5.—Bright mild steel in hydrochloric acid pickle; various inhibitors at 0·10% concentrations.

TABLE V.

INHIBITOR EFFICIENCY AT 0·1% CONCENTRATION, BRIGHT MILD STEEL IN COLD HYDROCHLORIC ACID PICKLE FOR PROLONGED TIME.

Sample No.	Inhibitor.	Loss in Weight of Test-pieces in Milligrams.							
		Pickling Time in Hours.							
		¼	½	1	2½	4½	24	48	72
1	None	12	13	18	25	37	156	549	976
2		11	11	15	20	30	149	531	992
3	A	7	7	10	11	14	22	27	38
4		6	6	8	10	12	21	30	41
5	B	7	7	10	11	13	18	29	40
6		8	8	10	12	14	20	29	39
7	C	13	14	14	16	19	61	135	212
8		8	8	9	13	15	57	131	207
9	D	9	9	11	13	14	18	22	24
10		9	9	12	12	15	19	24	29
11	E	9	9	11	12	15	22	30	37
12		8	8	9	11	13	18	24	31

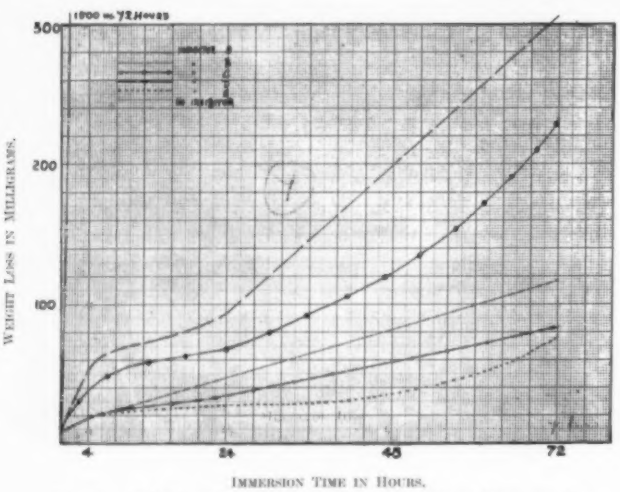


Fig. 7.—Bright mild steel in sulphuric acid pickle; various inhibitors at 0·10% concentration.

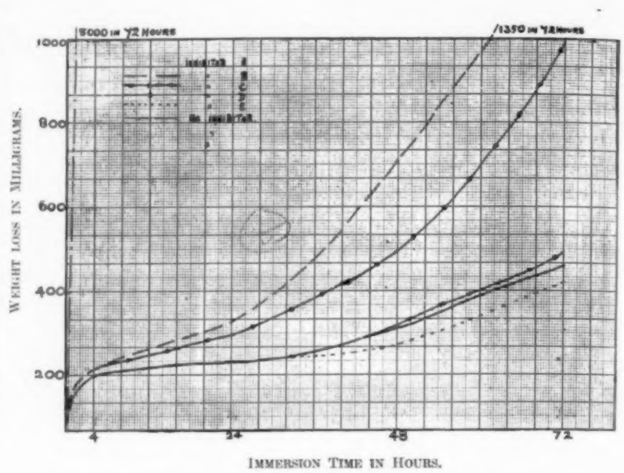


Fig. 8.—CRCA steel in sulphuric acid pickle; various inhibitors at 0·10% concentration.

TABLE III.

INHIBITIVE EFFICIENCY AT VARIOUS CONCENTRATIONS OF SEVERAL INHIBITORS.

Loss in Weight in Milligrams of Bright Mild Steel Pickled in 7% Sulphuric Acid at 70° C.

Sample No.	% of Inhibitor.	Inhibitor. A			B			C			D			E		
		Pickling Time in Hours.														
		¼	¾	17	¼	¾	17	¼	¾	17	¼	¾	17	¼	¾	17
1	0·0	399	1,102	2,003	—	—	—	—	—	—	—	—	—	—	—	—
2	0·0	334	1,108	1,978	—	—	—	—	—	—	—	—	—	—	—	—
3	0·05	33	72	106	19	38	44	20	54	62	83	239	249	35	44	61
4	0·05	37	81	115	15	34	44	22	53	61	88	299	317	37	49	97
5	0·10	22	65	109	5	14	19	18	41	50	60	119	123	20	27	75
6	0·10	16	44	75	5	18	22	14	37	42	44	87	89	21	31	75
7	0·50	9	24	53	6	12	19	7	22	27	33	60	68	10	18	33
8	0·50	8	22	52	6	14	19	7	19	28	33	62	70	11	20	45
9	1·0	8	13	34	5	13	18	8	20	26	34	47	50	11	14	27
10	1·0	8	19	41	5	12	14	5	16	23	26	40	45	15	20	32

TABLE IV.

INHIBITIVE EFFICIENCY AT VARIOUS CONCENTRATIONS OF SEVERAL INHIBITORS.

Loss in Weight in Milligrams of CRCA Steel Pickled in 7% Sulphuric Acid at 70° C.

Sample No.	% of Inhibitor.	Inhibitor. A			B			C			D			E		
		Pickling Time in Hours.														
		¼	¾	17	¼	¾	17	¼	¾	17	¼	¾	17	¼	¾	17
1	0·0	701	3,109	7,238	—	—	—	—	—	—	—	—	—	—	—	—
2	0·0	585	1,737	4,483	—	—	—	—	—	—	—	—	—	—	—	—
3	0·05	163	243	394	167	198	218	157	198	240	204	323	364	83	103	244
4	0·05	155	225	354	249	272	286	162	202	238	219	377	408	198	210	338
5	0·10	175	243	384	150	164	181	290	320	350	326	382	402	192	201	305
6	0·10	262	296	369	208	227	248	206	343	367	238	302	336	189	204	344
7	0·50	169	186	272	279	293	305	155	178	200	179	204	219	247	252	292
8	0·50	189	207	286	288	297	312	141	156	177	178	203	218	155	163	213
9	1·0	164	179	236	168	174	191	159	172	196	173	193	203	183	190	210
10	1·0	159	176	240	293	303	319	303	315	335	278	300	317	169	174	195

price values of the inhibitors are of little moment here, as the work detailed has been carried out under a specific set of conditions, which are typical average ones, but which in practice would vary considerably. Sufficient has, however, been said to demonstrate the efficiency of proprietary inhibitors from the practical and cost aspects.

Moreover, apart from the cost-saving on acid consumption, a feature which cannot be too highly stressed concerns the base iron or steel itself. The saving in acid consumed signifies the correspondingly lower dissolution of base metal, and therefore appreciably smaller inroad upon the metal surface, this minimising the development of pits, craters or other irregularities, and porous surface. Especially is this important with high-carbon steels and hardened articles, in which hydrogen embrittlement is prone to be induced. The carrying out of subsequent finishing operations, whether electroplate or enamelling, is facilitated. Also pickling processes become rather more congenial because of the considerable reduction of gas evolution with the acid/metal reaction diminished to practically nil.

The matter presented in this article specially applies to the treatment of miscellaneous small components in the general engineering factory or electroplating establishments. It is noted that these concerns in general do not realise the benefits which can be gained from the correct use of inhibitors. The heavier industries interested in sheet, strip, rod, etc., have more readily appreciated their merits on account of the larger acid consumption and thegreater work surfaces involved, whereas the lighter industries have not appeared to bother because of the relatively small acid consumptions and smaller work surfaces. It is thought that the above presentation demonstrates conclusively that this latter outlook is false, but that a cumulative saving as well as improved work are available, with no added complexities of process or additions to plant and space.

TABLE VI.

INHIBITOR EFFICIENCY AT 0·1% CONCENTRATION, C.R.C.A. MILD STEEL IN COLD HYDROCHLORIC ACID PICKLE FOR PROLONGED TIME.

Sample No.	Inhibitor.	Loss in Weight of Test-pieces in Milligrams.							
		Pickling Time in Hours.							
		¼	½	1	2½	4½	24	48	72
1	None	135	136	143	157	185	659	1,938	5,275
2		145	146	153	164	200	677	2,289	6,282
3	A	158	158	163	163	170	191	212	237
4		145	147	152	158	161	179	206	234
5	B	165	167	171	177	182	186	202	221
6		139	143	144	149	151	158	169	180
7	C	158	158	162	170	173	200	263	348
8		155	155	160	167	169	199	255	330
9	D	159	159	163	164	167	171	178	186
10		142	143	148	149	151	157	164	177
11	E	155	155	162	170	172	182	190	204
12		138	139	142	145	147	156	165	177

TABLE VII.

INHIBITOR EFFICIENCY AT 0·1% CONCENTRATION, BRIGHT MILD STEEL IN HOT 7% SULPHURIC ACID PICKLE FOR PROLONGED TIME.

Sample No.	Inhibitor.	Loss in Weight of Test-pieces in Milligrams.							
		Pickling Time in Hours.							
		¼	½	1	2½	4½	24	48	72
1	None	115	150	228	811	1,181	1,551	1,587	1,603
2		163	194	225	737	1,050	1,393	1,412	1,415
3	A	10	12	12	20	20	43	73	115
4		11	13	13	20	20	44	82	119
5	B	14	17	18	38	61	97	170	298
6		12	15	18	32	48	89	216	340
7	C	7	9	9	19	19	33	60	71
8		9	10	11	16	22	37	61	97
9	D	15	18	20	32	43	68	130	224
10		14	15	18	25	35	66	121	243
11	E	10	10	10	14	18	32	59	86
12		8	10	10	13	17	25	43	69

TABLE VIII.

INHIBITOR EFFICIENCY AT 0·1% CONCENTRATION, CRCA. MILD STEEL IN HOT 7% SULPHURIC ACID PICKLE FOR PROLONGED TIME.

Sample No.	Inhibitor.	Loss in Weight of Test-pieces in Milligrams.							
		Pickling Time in Hours.							
		¼	½	1	2½	4½	24	48	72
1	None	505	588	750	2,342	5,101	7,919	8,130	8,197
2		470	593	866	3,508	6,538	7,642	7,762	7,776
3	A	189	194	197	206	218	250	346	499
4		158	160	164	175	186	217	297	427
5	B	170	177	182	206	241	388	837	1,737
6		143	151	154	172	196	276	603	1,006
7	C	162	165	167	175	184	214	316	506
8		196	200	200	211	220	241	329	516
9	D	187	191	194	212	230	306	527	1,071
10		172	175	179	196	215	290	478	982
11	E	164	169	169	179	186	251	272	359
12		195	197	199	209	217	231	279	336

Institute of Metals Appeal

The Institute of Metals is appealing for the establishment of an endowment fund having the objects of placing the finances of the Institute on a sound and more permanent basis, assisting the publications of the Institute and extending the scope of the services offered by the Institute to members and to the non-ferrous metal industries generally.

Correction

In the review of exhibits at the Birmingham Section of the British Industries Fair, published in our last issue, the first complete paragraph near the top of the first column on page 125 should have been in advance of the previous paragraph. We trust no reader has been inconvenienced by the inaccurate transposition.—EDITOR.

Smoke and Fume Cleansed by Supersound Wave

What may prove a solution to the smoke nuisance is a device which has been developed by Mr. H. W. St. Clair, a metallurgist of the U.S. Bureau of Mines. It has long been known that, when sound waves are passed through a tube containing a fine powder, the powder will be concentrated at points that are free from vibratory motion. It has also been known that waves of extremely high frequency affected the diffusion of solid or liquid particles in a gas. However, no practical application has previously been made of this knowledge.

The St. Clair method merely passes the smoke or fume through a tube in which standing sound waves are established. These standing waves are produced by so adjusting the length of the tube that waves reflected from the upper end are in phase with the original sound waves set up at the lower end. In order that the process may work at its best, the wave-length used must be approximately equal to the diameter of the tube. For a tube of practicable diameter, this means that the frequencies used will vary from 3–20 kilocycles per sec. A person of acute hearing can detect waves of frequencies up to about 5 kilocycles ; those of greater frequency are above the auditory range and hence are sometimes called " super-sonic."

To generate sound waves of this frequency, several types of equipment may be used. Mr. St. Clair uses what is technically known as the magneto-strictive method, but for purposes of popular demonstration, an acoustic generator is used. This, in fact, is merely a shrill whistle. The sound waves produced by the whistle are reflected in phase with the original waves from the top of the tube and cause the solid particles to fall out of the gas stream.

For many years past the Bureau of Mines has been interested in the problem of smelter fumes, which has long been the source of expensive litigation, due to suits brought by property owners charging damage to vegetation, live stock and water supplies. It is claimed that the device will be of real help in solving this problem and also help to curb the smoke nuisance in large cities, which has been responsible for injury to property and health.

Non-Ferrous Welding

The art of welding has attained great importance in recent years, particularly in providing a means of jointing metals so that their essential properties are preserved at the junction. The subject was discussed by Mr. H. W. G. Hignett at a recent meeting of the Midland Metallurgical Societies, in which particular attention was directed to the welding of non-ferrous metals, a summary of which is given here.

THE choice of a suitable material for a desired component depends on the physical and chemical properties required, and upon the length of service desired. Non-ferrous metals have wide applications, and are chosen where their resistance to corrosion, thermal or electrical conductivity, or other characteristics outweigh their higher relative cost. But, as with ferrous metals, the jointing of parts must preserve, as far as possible, the essential properties, and in most cases welding is the only process to fulfil this requirement.

Although methods analagous to the forge-welding of mild steel can be used for aluminium and nickel, the processes used commercially in this country are oxy-coal gas, oxy-hydrogen, oxy-acetylene, carbon arc, metallic arc, atomic hydrogen and electric resistance spot, seam, butt and flash welding. The choice of method is dependent upon the properties of the material.

Oxy-coal gas and oxy-hydrogen flames, of temperature less than two-thirds that of oxy-acetylene, are easier to use than the latter for low melting point materials like lead and aluminium. Low welding speed, however, produces wide annealing zones, and the large amount of water vapour produced as a product of combustion, is liable to cause oxidation of the molten metal. Acetylene is unique in developing an extremely high temperature in a zone of the flame which is admirably suited to welding. It is, consequently, applicable to nearly every known weldable material, and can give excellent results on each. Such results demand, however, skilled technique and consistently accurate control of the flame conditions. The emphasis laid on the need for accurate flame control may appear excessive, if it is not realised that flame variation has two very serious consequences: first, the probability of variation great enough to harm the weld before being noticed by the operator; and secondly, the psychological effect on the welder whose attention is continually distracted.

The materials commonly welded by the oxy-acetylene process in this country are lead, copper and its alloys, nickel and its alloys, aluminium and its alloys, zinc alloys and magnesium. The development of deoxidised copper has greatly simplified the welder's task with this metal, but conflicting opinions are still held as to the correct technique to be adopted. The conflicts would probably not arise if full consideration were given to the varying nature of the factors which govern technique.

It may be admirable practice to hammer one particular seam; this is essential if there is any oxide in the copper, if the pieces welded are heavy and under constraint, or if the contents of arsenic, antimony, bismuth or lead exceed certain values. On the other hand, it may be equally good practice to complete the seam before hammering. It is only necessary to bear in mind that the treatment of a weld in deoxidised copper should not encourage grain growth at the boundaries of the weld, and, therefore, hammering must be continued below the recrystallisation temperature. Also arguments for and against the use of fluxes are most futile; the purpose of the flux is to reduce surface tension, and to prevent solution of surface oxide films by the molten metal. The only essential is that the flux, if used, should not produce inclusions in the weld. With or without hot or cold hammering, and with or without a flux, it should be possible to produce welds in deoxidised copper having a minimum tensile strength of 11 tons per sq. in. after removal of the excess weld metal.

Brasses are welded with a definitely oxidising flame; bronzes are usually treated like copper; and silicon bronzes, with such alloys as "Everdur," are remarkable for their good welding properties. Nickel and its alloys possess a hot-short range, so that care is necessary to avoid the generation of stress in the seam during cooling through this range. The non-heat-treated aluminium alloys and the magnesium-silicide alloys can be welded satisfactorily, but the others suffer serious diminution in mechanical properties when welded. The oxy-acetylene process has been found most satisfactory for magnesium alloys. These require a special flux, every trace of which must be removed after welding.

In its modern form, controlled by intense magnetic fields, and with various types of gas-shielding devices, the carbon arc possesses many advantages for automatic welding. Expensive-coated electrodes are unnecessary, the heating is more local than with oxy-acetylene, distortion being consequently reduced. Unfortunately, it is very difficult to prevent oxidation of the weld metal by this process, and its applications to non-ferrous materials are therefore limited. It is used in the United States for jointing copper with a phosphor-bronze filler rod, and is recommended for repair work on aluminium castings.

Metallic arc welding of non-ferrous metals is limited in its progress by the amount of attention which the electrode manufacturers have to spare from their frenzied efforts to make cheaper electrodes for mild steel. Until quite recently no serious efforts had been made to produce satisfactory coated electrodes for non-ferrous metals. The advantages of the metallic arc process are high welding speed and reduced distortion; but it produces high residual stress, and there is need for careful preparation of the work. The very local heating makes the process readily applicable to materials of low-thermal conductivity, if the results of internal stress can be avoided. With the latest types of electrode, welds on nickel and alloys can be produced to compare favourably with the best oxy-acetylene welds. The copper alloys, containing manganese and silicon such as "Everdur," are readily welded by the metallic arc with excellent results.

Atomic hydrogen welding utilises the heat of recombination of hydrogen atoms produced by passing the gas through a tungsten arc. The temperature produced is 3,700° C., and makes possible very high welding speeds. The reducing action makes a flux unnecessary in most cases, but aluminium is an exception. This process is particularly suitable for high-melting point nickel-chromium alloys, for Monel metal and for such applications as high-vacuum plant.

The application of spot and seam welding by the electric-resistance process to non-ferrous metals has received a great impetus from the development of control devices which permit welding times as short as a half-cycle. It has been found possible to make welds in many materials by a process of recrystallisation across the interface, and to avoid any structural disturbance of the outer surfaces. In commercial practice, however, fusion usually takes place in spot and seam welds in non-ferrous materials, and, as many of them have a narrow plastic range, the control of electrode pressure is much more important than for mild steel. Spot welders, utilising the discharge of a condenser or a self-induction coil to make the weld, have been developed, and appear to have great possibilities.

Problems of Alloy Structure

Mechanical and electrical engineering, so essential to modern civilisation, are based on the use of metals and alloys. Each discovery of an alloy with improved qualities enlarges the scope of what the engineer can do. In a recent paper before the Royal Society of Arts Professor W. L. Bragg, O.B.E., M.A., D.Sc., F.R.S., outlined the various ways in which problems of alloy structure are being attacked in order that progress may be made on ordered lines. In this article it is only possible to summarise his views.

THE term " alloy " was originally used in a derogatory sense, as indicating that a metal had been contaminated with some impurity, or that a noble metal had been rendered less valuable by the addition of a base metal. It has entirely lost this significance. It has been found that such mixtures of metals are in general superior to pure metals as regards the properties which are useful for technical purposes. Although iron is the most common of metals, it is extremely difficult to obtain it in the pure state ; the pure metal is soft, and would be useless from a mechanical point of view. A little carbon turns it into tough and elastic steel, and an increased amount into rigid cast iron. Alloyed with chromium it becomes stainless steel, which resists rust and corrosion. Brass and bronze are two alloys of immense age and respectability, and have more attractive properties than the metals from which they are made. Aluminium as a metal has the desirable property of lightness, but is mechanically weak. The much more tenacious duralumin is formed by putting small quantities of other metals, mainly copper and magnesium, in the aluminium. The most modest advance on the strength of steel has an enormous effect on the design of structures, and the discovery of a really light alloy with the properties of steel would have incalculable consequences.

The position at the present time is very interesting, because the sciences of metallurgy and physics are being applied together to the study of metals and alloys. Metallurgy embraces the study of the mechanical properties, such as tensile strength, hardness, yield point, and elastic constants of alloys of different composition. It studies the effects of quenching, annealing and tempering. The attack from the physical side is based on atomic structure itself. Quantum mechanics is applied to study the nature of the metallic state. X-ray analysis is applied to discover the mode of arrangement of the atoms in metals and alloys. An attempt is made to explain the properties of alloys in terms of their atomic structure, and success along these lines must lead to success in predicting what new combinations of metals are likely to lead to alloys with still more advantageous properties.

The Nature of the Metallic State

A metallic substance has certain peculiar properties, rather hard to define exactly, but instinctively appreciated, which differentiate it from substances of other kinds. It has a characteristic lustre due to its high reflecting power for light, and in many cases a toughness and ductility, a power of being forged and bent without cracking or losing its strength, which make it so useful mechanically. Metals are excellent electrical conductors.

The reason for these properties is very fundamental, and is bound up with the nature of atomic structure. Metallurgy studies associations of electropositive atoms. Each atom in a separate state has one or more loosely-held electrons. When such atoms come together to form a metal, one may regard all the loosely-held electrons as grouped together to form a common pool or negative atmosphere in which the positive metallic ions are embedded. Bonds between the ions are of minor importance. The forces holding the solid together arise from the attraction between the ions and the general cloud of electrons.

Our ideal of a metal or alloy as a set of positive ions, embedded in a common electronic atmosphere, suggests a general qualitative explanation of the typical metallic features. It explains electrical conductivity, by the drift of the " free " electrons through the metal. Such a structure has a self-healing property if distorted. No important interatomic bonds are broken and the general attraction between ions and electrons, which can flow freely so as to adjust potentials in the breaches where the arrangement is disturbed, continues to hold the whole structure together. Hence the toughness and ductility of metals. In alloys, each electropositive atom, of whatever kind, brings its passport in the form of loosely-held electrons to add to the common stock, and all are welcome to the association. Hence the power of metals to mix freely in all proportions, or with wide ranges of proportion.

There is another feature of alloys which is very characteristic. This is the extraordinarily free way in which atoms can move about inside the alloy *in the solid state.* When an ingot of an alloy is first cast, it is generally far from homogeneous. The first crystals to form from the melt are richer than the melt itself in one constituent, and may differ greatly in composition from the last parts to solidify. Yet such an ingot, held for some time at a temperature well below the melting point, becomes homogeneous. Atoms freely migrate through its solid structure so as to adjust differences in composition. Such movements can take place during slow cooling or annealing, and can be arrested by rapid cooling or quenching from a high temperature. The heat-treatment of alloys, so important for technical purposes, is based on this phenomenon. It is again a result of the association of ions and electrons, which permits atoms to interchange place in the structure without breaking it down.

Alloy Phases

Professor Bragg showed a series of what are termed " phase diagrams " to assist in explaining the theory of the structure of metals. All the phases were crystalline, and their structure can be studied by means of X-rays. In general it is necessary to use the Debye-Scherrer (powder) method of analysis. This method of analysis, useful for crystals of all types, was first applied to alloy structures by Westgren, who showed that *each phase has a different crystalline structure* ; in every phase, however, each atom is surrounded by many others at nearly equal distances, as if the atoms were like balls packed together closely.

There is one curious feature of these phase-patterns which gives us a hint as to their nature: the positions for the atoms of different nature which compose them are rigidly fixed by the structure. These positions cannot be changed without a breakdown of the very essence of the structure.

Discussing causes for the determination of the phase pattern, Professor Bragg stated that it was first pointed out by Hume-Rothery that the electron-atom ratio is of prime importance in determining phase-pattern. *Similar phase-patterns have the same ratio of free electrons to atoms.* The metallic state can be regarded as one in which positive ions (metal atoms) are embedded in a common atmosphere of electrons. If we add monovalent gold to copper, each gold atom with its one loosely-held electron replaces a copper atom with one similar electron. The ratio of electrons to atoms remains one to one. If now a divalent

zinc atom replaces a copper atom, it brings two electrons to the copper's one electron, and so increases the ration of electrons to atoms. When the ratio has grown to 1.38 the α phase ends, as if that particular structure could not tolerate a higher ratio. If now we add trivalent aluminium each aluminium brings in three electrons. The α phase ends earlier (in atomic ratio), but we again find that the *limiting electron-atom ratio* is 1·41, not far different from that in Cu-Zn. The β phases are grouped around a ratio of about 1·48, the γ phases in a region where the ration is in the neighbourhood of 1·6. This fits in with our concept of the metallic state. We must regard these intermetallic phases as the result, not of combinations of atoms of metal A with atoms of metal B in definite proportions, but as combinations of both metals A and B on the one hand with electrons on the other hand. A rule of combining proportions holds between metal atoms and electrons. A very attractive theoretical explanation of these rules has been put forward by H. Jones.

Atomic Distribution in Phase-Patterns

A further phenomenon in alloys which casts much light on their nature is the Order-Disorder change which some exhibit. The existence of such an ordering was first divined by Tammann, and proved actually to exist by Johansson and Linde. Picture an alloy at low temperatures in perfect order. As it is warmed up, the agitation of the atoms due temperature begins to cause atoms here and there to be shuffled out of their right places. Instead of A B A B A B in a row, we get A B B A A B. Further increase of temperature increases the probability that any given pair of atoms will get a hard blow. In addition, the more atoms are already out of phase, the less will be the energy holding any given atom in its right place. This energy is a maximum when all its neighbours are also in their right places. If some of them are wrong, the distinction between "right" and "wrong" is less marked. Hence, an atom gets harder blows, and is more easily knocked out of place, as temperature rises. The two effects interact in such a way that complete demoralisation sets in, and the ordered structure disappears finally with a rush at a definite critical temperature. These rearrangements of atoms taking place within the solid structure of the alloy, can be followed by X-ray analysis. Many curious features of alloy behaviour, previously difficult to account for, are explained by them. They influence density, electrical resistance, magnetic properties, and specific heat, often in a marked degree.

Corrosion

THE magnitude of the work being done by the Corrosion Committee, a joint committee of the Iron and Steel Institute and the British Iron and Steel Federation, was stressed by Dr. W. H. Hatfield, F.R.S., in a lecture on the above subject at a recent meeting of the Manchester Metallurgical Society. The results of much earlier study of corrosion in relation to ferrous metals proved to be of little value because little or nothing was known of the manufacturing conditions under which the specimens were produced. In the work of the Corrosion Committee, the complete history of each specimen is known, and the data obtained provide a very important contribution to our knowledge on the subject and means of combating it.

Dr. Hatfield referred briefly to part of the work being carried out on atmospheric and marine corrosion. In the former, mention was made of exposure tests in 14 stations, situated in different parts of the world, at which three series of materials were under test, including ordinary mild steel, two copper-bearing mild steels, ingot iron, and various wrought irons, together with several low-alloy high-tensile structural steels. Quantitative results are available for the corrosion of unpainted specimens exposed for periods up to five years at several of these corrosion stations, and obversations on painted specimens of the various materials are published in the Committee's Report. The data indicate what are to be taken as the normal rates of corrosion of ordinary ferrous metals when freely exposed to the atmosphere in various parts of the world. Work on marine corrosion has been actively prosecuted: it is being studied in two ways: by observations on specially prepared and full-size plates built into actual ships, and by the exposure of relatively small stationary specimens. A series of tests are in progress on an Admiralty trawler, while much work was done on a barge, which was unfortunately sunk in a recent collision on the Thames. Exposure tests of stationary specimens are in progress at Gosport. One of the main conclusions to date is that ships plates painted with white lead whilst still hot at the mill give good results.

Discussing the resistance to corrosion of modern steels in comparison with pre-war steels, Dr. Hatfield stated that many consider pre-war steels have greater resistance, but it was considered that post-war steels are by no means inferior in this respect, though more severe service conditions may make them appear so. The process of manufacture and the composition of the furnace charge probably have no effect on the resistance of steel to corrosion except in so far as its composition may be materially altered. Wrought iron has been found to be rather more resistant to atmospheric corrosion than mild steel or ingot iron; the nature of the rolling scale is probably one of the factors causing this difference. From an economic point of view, the addition of alloying elements in moderate proportions to steel is undoubtedly justified; the case of copper was mentioned.

Rustless Steels

It seems difficult to realise that rustless steel was developed little more than twenty years ago—a steel the manufacture of which had been regarded as an impossible dream. The discovery, by Mr. Harry Brearley, of the corrosion-resisting properties of a steel alloyed with chromium led to the development of stainless cutlery. It is generally assumed that developments of this character lead to considerably increased cost, but it is interesting to note, as Dr. Hatfield stated, that while shear steel, formerly used for cutlery, cost about 10d. per lb., stainless steel for cutlery is now sold at about 6d. per lb.

It was found that the chromium steels, containing sufficient chromium to provide rustless properties, offered considerable resistance to attack by nitric acid, but less resistance to attack by sulphuric and hydrochloric acid, and as a result of numerous investigations, it was found that the addition of nickel to chromium steels, in suitable proportions, an alloy was produced which resisted attack by any of these acids. To-day there is a wide range of alloy steels which are highly resistant to attack by different corrosive media, possessing properties suitable for almost every possible class of work. Practically all these latter steels are based on the 18/8 chromium-nickel steel originally developed with a low carbon content; other elements, however, are now added to improve certain properties, one of the most useful being molybdenum, with the resistance of the 18/8 steel to hot, strong solutions of acetic acid, to dilute solutions of sulphuric acid, etc. Stainless steels are available for a wide range which possess great ductility and malleability and which give excellent results on deep press work.

Tungsten: Its Uses and Manufacture

The importance of tungsten in the manufacture of certain types of alloy steels is generally recognised, but the manufacture of this material in a form suitable to the steel maker is not so well known. The subject was discussed by Mr. Julius L. F. Vogel in a recent paper before a meeting of the Tavoy Chamber of Mines, Burma, extracts of which are given in this article.

THE highest grades of high-speed steel for use as cutting tools contain 18 to 22% tungsten, 3 to 4% chromium, 0·5 to 1·5% vanadium, with occasionally cobalt, molybdenum, or other alloy metals employed by different steel makers to obtain special properties in tools for particular purposes. The carbon present in high-speed steel is lower than in straight carbon tool steel, and it is combined with tungsten and other alloying elements forming a complex hard structure, which, on fracture shows a fine silky appearance. The essential function of tungsten as an alloy metal in steel is to give to the alloy steel hardness and toughness, which are maintained even when the alloy steel is heated to a high temperature.

The delicate structure produced in the alloy steel may be damaged considerably by the presence of impurities such as sulphur, phosphorus, arsenic, tin and occluded gases, such as nitrogen and hydrogen. The danger of these and other impurities has been proved conclusively, and this accounts for the stringent specifications for ferro-alloys and alloy metals imposed by high-speed steel makers. At the same time, it should be appreciated that alloy steel made from the best materials, in correct proportions, may be satisfactory or otherwise, according to the heat-treatment it has undergone.

The activity of the engineering industries is the primary factor in the demand for minerals. It must be borne in mind, however, that the tungsten contained in scrap high-speed steel, whether produced in course of manufacturing tools or returned worn tools, can be recovered almost entirely on remelting. Consequently, times of intense activity, demanding large supplies of wolfram and enabling good prices, carry within them the seeds of a slump in demand and value. The slump in the wolfram which followed the great war was due probably as much to the huge quantity of remeltable tungsten steel scrap as to the reduced demand for alloy steel. Another factor affecting the demand for wolfram is the partial substitution of molybdenum for tungsten in high-speed steel. At equal costs tungsten is preferred as the chief alloy constituent, but satisfactory high-speed steel can be made with molybdenum.

The form in which steel makers require tungsten has gone through a series of modifications. The first use of tungsten in steel dates back to the year 1857, when Robert Mushet, of Sheffield, introduced a steel containing 2 to 5 or 6% of tungsten, which had remarkable cutting power in comparison with carbon steel. Mushet steel was made by adding wolfram concentrates directly into the crucibles in which the steel was melted. The use of Mushet steel was very limited, and it was employed only for occasional jobs, but in the Paris Exhibition of 1900 an American product, made by the Taylor-White process, caused a sensation which led to intensive investigation into improved tool steel capable of taking deeper cuts and of working at higher speeds. Sheffield very soon was in the forefront, and the development of the use of high-speed steel was hindered only by the inability of old machines to stand up to the strain of work possible with the improved tools. Steel makers and machine-tool makers, however, working in parallel, gradually provided the engineering industry with machines and tools capable of cutting metals at speeds which raised the tool points to a visible red heat. It was by the constantly increasing percentage of tungsten used in these steels that the ability of the tools to maintain their hardness at such temperature was obtained.

High Speed Steel Alloys Mining Co., Ltd.

Aletaung Workings of the Widnes Mine, Tavoy, Burma.

Originally, high-speed steel was made in crucibles and, to obtain uniformity of large numbers of small ingots, accurate adjustment of the charge in each crucible is necessary. Further, in crucible melting, it is desirable to work with a minimum of covering slag, and steel makers prepared very stringent specifications for all ingredients, including tungsten, which they required in powder form for accurate weighing. The substitution of crucible melting by electric furnaces, especially high-frequency furnaces, has led to a change. The higher temperatures and larger charges of these furnaces made it possible to work with more slag to refine the steel and the lower melting-point of ferro-tungsten made thorough mixing of the charge easier.

Gradually, ferro-tungsten consumption has increased at the expense of tungsten metal powder, but the standard British grade of 98 to 99% powder is still in considerable demand. The essential difference between the two is, that for tungsten metal powder the tungsten trioxide in the ore is separated chemically from all the other elements, while for ferro, the mineral is smelted directly. In the production of powder it is possible to work with low-grade and impure raw materials. For ferro-tungsten, however, a closer consideration of the quality of the raw material is needed, and the two methods of manufacture—electric furnace and alumino-thermic—involve different problems. In electric furnace work certain impurities, for instance, tin, are not seriously detrimental as they can be eliminated by maintaining the charge at the high temperature of the furnace to bring about volatilisation, but close limits are placed on manganese, silicon, lime and other impurities, the quality of the mineral, therefore, still needs careful watching.

Standard ferro-tungsten must assay over 80% tungsten,

High Speed Steel Alloys Mining Co., Ltd.

Part of the Magnetic Separation Plant, Tavoy.

and by using mineral very high in iron this percentage cannot be obtained. Again, highly manganiferous minerals require the addition of iron and precautions to avoid an excess of manganese in the product. It is often necessary to roast minerals before reduction, to eliminate excessive quantities of arsenic and sulphur. To obtain the best raw material for the process it is generally advisable to mix different types of ores to secure a proper balance between iron and manganese and the necessary minimum of tin and other impurities. The addition of some scheelite (calcium tungstate mineral) is often useful, and this is generally low in impurities. Typical assays of tungsten powder and ferro-tungsten are given in Table I.

TABLE I.

Tungsten Metal Powder.

Standard Specifications.

	%	%	%
Tungsten	98/99	99 minimum	99·50 minimum
Carbon	0·15 maximum	0·10 maximum	0·05 maximum

Commercially free from deleterious impurities.

Typical Analyses.

	%	%	%
Tungsten	98·50	99·30	99·62
Silica	0·30	0·25	0·15
Iron	0·18	0·15	0·09
Carbon	0·12	0·05	0·03
Sulphur	0·05	0·03	0·02
Phosphorus	0·01	0·01	0·01
Tin	Nil	Nil	Nil
Manganese	Trace	Trace	Trace
Lime	Trace	Trace	Trace

Ferro-Tungsten.

Standard Specifications.

	%
Tungsten	80/85
Carbon	0·10 maximum

Typical Analyses.

	%
Tungsten	82·50
Silicon	0·57
Carbon	0·05
Sulphur	0·03
Phosphorus	0·02
Tin	0·10
Manganese	0·28

Second Conference on Industrial Physics

The second Conference on Industrial Physics will be held under the auspices of the Institute of Physics in Birmingham from March 18 to 20 next. The subject of the Conference is "Optical Devices in Research and Industry." An Exhibition of instruments, apparatus and books cognate to the subject of the Conference is being arranged, and will be held in the Physics Laboratories of the University of Birmingham. A section will be devoted to popular applications of optical devices, including photo-cells. The Presidential Address on "Spectroscopy in Industry" will be delivered by Prof. A. Fowler, C.B.E., D.Sc., A.R.C.S., F.Inst.P., F.R.S., and in addition lectures and discussions on the following subjects are being arranged: "Colorimetry, Spectrophotometry and the inspection of manufactured products for 'appearance,'" "Polarimeters, Saccharimeters and Refractometers in Sugar, Jam-boiling and other Industries," "The Application of Electron Diffraction to Industrial Problems," "Industrial Uses of Photocells," "Optical Gauges for Metrology and Engineering." It is intended that the lectures and discussions shall be informal in character; they will deal particularly with applications of the subject to industrial problems. Visits to local works and research laboratories will be included in the programme and a Conference dinner will be held. There will be no Conference fee and membership is open to all interested. Further particulars may be obtained from the Secretary, The Institute of Physics, 1, Lowther Gardens, Exhibition Road, London, S.W. 7.

Speeding Steel Section Production

(Continued from page 138.)

the company, to manipulate the plate for shearing on a dead roller bed, which is a continuation of the cooling-bank delivery rack. The side-cutting is done first, and the plates are then passed through the cross-cutting shears. One operator only is required on each side-cutting shear, all the motions of the shears and plate-handling machines being effected by remote control. After passing through the cross-cut shears, the plates pass along a rack on which are three throw-off tables, where the rectangular plates, being finished, are thrown off on to the floor to be sorted out, and loaded by overhead cranes fitted with beams and magnets.

Plates to be cut to sketches pass over the above-mentioned racks, and over a chain conveyer into a cross bay which is common to both mills. In this bay are two hydraulically operated sketch shears surrounded with castors, and so arranged that plates from either mill can be easily brought to either shears. The bay is served by a 15-ton overhead crane with a magnet beam.

Plates 100 ft. long by 8 ft. wide, and $\frac{1}{4}$ in. thick, have been rolled in the 10-ft. mill, which regularly rolls plates $1\frac{1}{2}$ in. thick and over down to $\frac{3}{16}$ in. thick, and weighing up to over 10 tons each when sheared. These particulars illustrate the great elasticity of the mill, which has a production capacity exceeding 6,000 tons per week, rolling plate $\frac{5}{8}$ in. thick.

The combined works occupy about 540 acres, and contain more than 54 miles of railway lines and sidings. It is noteworthy that they include a constructional department which has a capacity of fabricated material of medium weight up to 3,000 tons per month, and, in addition, has an output of colliery materials comprising mine arches, roof supports, steel pit props, and patent collapsible steel pit props of unique design, of approximately 1,200 tons per month.

Institute of Metals

ANNUAL GENERAL MEETING IN LONDON

THE twenty-ninth annual general meeting of the Institute of Metals, held in London on March 10 and 11, 1937, at which several announcements of an important character were made by the President, Mr. W. R. Barclay, O.B.E. For some time the need for co-operation between metallurgical institutes has been recognised, and the announcement that a scheme has been effected between the Iron and Steel Institute and the Institute of Metals will be welcomed by the members of these two institutes. Another and more detailed announcement was made by the President with regard to an endowment fund, designed to place the finances of the Institute on a sound and more permanent basis, to assist the publications of the Institute and extend the scope of the services offered. It is noteworthy that promises of actual contributions amount to nearly £14,000. Mr. Barclay made a very strong appeal to the non-ferrous industry to supply funds, not only to rectify the present unsatisfactory financial position, but to provide such resources as would ensure a continuous and progressive extension of the Institute's work in the future.

The report of the Council indicates that the year has been a notable one in many ways, particularly in that the constitution and method of election of the Council has been revised and rendered potentially more representative of the members, and that a scheme of active co-operation with the American Institution of Mining and Metallurgical Engineers has been successfully negotiated. Another event calling for special note is the holding of the first meeting in France. The technical papers presented at this meeting were very comprehensive, in this review, however, it is only possible to summarise them.

The Theory of Age-Hardening

This paper, by Dr. Marie L. V. Gayler, forms part of a research carried out for the Metallurgy Research Board of the Department of Scientific and Industrial Research. A general theory of age-hardening is put forward, based on data relating mainly to the age-hardening of alloys of the duralumin type and of beryllium-copper and silver-copper alloys. The theory is in general agreement with that put forward recently in a contribution on "Ageing Phenomena in a Silver-Rich Copper Alloy," by Cohen[1]. There are differences, however, in interpretation of the first stage of the ageing process and of the intermediate softening; also the existence of a maximum has been shown to exist on the maximum hardness-temperature curves of the first stage of the ageing process as well as on that of the second.

Age-hardening takes place by two processes: (*i*) diffusion, and (*ii*) precipitation, the second overlapping the first Both processes take place within wide temperature limits which are peculiar to every alloy system—*i.e.*, the "temperature range." The rate at which each process takes place depends, apart from other factors, on the temperature of ageing. The limits of the temperature range are interminate, but approximations can be obtained for all practical purposes. If the temperature of ageing be close to the lower limit, both stages of the ageing will take place excessively slowly; if the temperature of ageing be close to the upper limit, the first stage will proceed so rapidly that its effect will not be detected. Each of the two processes is characterised by changes in physical properties which will present maxima or minima, depending on the ageing temperature, the characteristics of the first being gradually replaced by those of the second. The softening which occurs when an alloy is aged at a higher temperature, after being previously aged at a lower temperature, is now explained in the light of the new theory.

Curves are given representing the relationships between (*i*) hardness and duration of ageing, (*ii*) maximum hardness and temperature of ageing, and (*iii*) time of attaining maximum hardness and temperature of ageing.

Metal Spraying: Processes and Some Characteristics of the Deposits

During recent years new designs of metal-spraying apparatus have been developed, using wire, powder and molten metal. Many applications have been successfully exploited, and the object of this paper by Mr. E. C. Rollason is to indicate briefly the capabilities of the various processes and the characteristics, such as porosity, hardness and corrosion-resistance of the deposit. Spraying pistols using wire, powder and molten metal are described, together with comparative details. The nature of the sprayed deposit is discussed. A few corrosion tests, using intermittent salt-spray have been made on zinc and aluminium deposits and on painted zinc coats.

Using the three types of pistol, comparative tests of aluminised surfaces have been made and heat-treated nickel-chromium-iron coatings were found to have good resistance to oxidation at elevated temperatures. Data are also given for porosity, oxide content of sprayed copper, and hardness of sprayed metals. From the investigation it appears that each of the three types has characteristic advantages which will allow all of them to survive competition and become useful tools in the engineers' hands.

Owing to its low costs, the powder process will undoubtedly prove successful in spraying large surfaces with zinc, especially when the coat is subsequently painted. This powder-spraying pistol also offers possibilities of spraying brittle metals and alloys of high melting point which could not be drawn into wire, although deposits of the higher melting point metals which have been examined are not wholly satisfactory as yet.

The molten metal instrument can produce thick coatings of the low melting point metals at a reasonable price, and should prove useful to the galvanizer doing contract work especially as the metal in ingot form is used and neither acetylene nor oxygen is required. The wire pistol, on the other hand, will without doubt hold the field in building up thick deposits on worn articles and also for producing heat-resisting surfaces. Even in the production of zinc coating where she cost is higher than in the case of other processes the wire pistol offers advantages in the spraying of internal work.

The Effect of the Addition of Small Percentages of Iron and Silicon to a High-Purity 4% Copper-Aluminium Alloy

In this investigation, by Dr. Marie L. V. Gayler, the constitution and age-hardening of the quaternary aluminium alloys containing 4% copper and up to 0·6% iron and 1% silicon has been studied.

It has not been possible to attain a state approaching equilibrium in these alloys under the conditions of casting and subsequent working and heat-treatment described.

The phases $CuAl_2$, αFeSi, βFeSi, and silicon have been identified in the alloys, but $FeAl_3$ was not observed. Silicon is held in solid solution to a limited amount at 500° C., and is precipitated during slow cooling to 190° C. together with $CuAl_2$.

The results indicate that the addition of 0·1% iron inhibits the age-hardening of a 4% copper alloy at room

[1] M. Cohen, Metals Technology, 1936, 3 (7); A.I.M.M.E., Tech. Publ. No. 751.

temperature but not at high temperatures, while the addition of 0·6% iron reduces, to a marked extent, ageing at high temperatures. The addition of 1·0% silicon does not inhibit the effect of 0·6% iron. It would appear that the age-hardening which takes place at high temperatures may be attributed to the precipitation of silicon as well as of $CuA6_2$

The Effect of Cast Structure on the Rolling Properties of Zinc

The research described in this paper by Dr. L. Northcott was initiated to investigate the difficulties encountered in the first stages of breaking down chill-cast ingots. Some metals and alloys are liable to fracture when rolled or forged in ingot form, and require careful manipulation in the initial stages of working. In many instances difficulty in breaking down has been found to coincide with a coarse columnar type of crystal structure. This paper deals with the first section of the research and is concerned with zinc of 99·9% purity.

The examination of ingots made by utilizing directional solidification showed that the directional properties of the zinc crystals are such that in columnar form the strength measured in the direction of growth is about four times that at right angles to it. Less pronounced differences were observed in the notched-bar impact values. The selective weakness of the metal along one set of crystal planes was also demonstrated by the tearing action of the cutting tool when machining in certain directions, and resulted in the development of a number of surface cracks. The weak plane was shown by X-ray examination to be the basal (0001) plane of the hexagon.

The connection between cold-working and the absence of columnar crystals was investigated by determining the degree of hot-working necessary to permit subsequent cold-working and correlating the results with the accompanying changes in structure. Provided that the initial hot reduction was not less than about 40%, rolling could be completed satisfactorily in the cold. Hot-rolling was found to be associated with recrystallisation and consequent release of internal stress; recrystallisation was almost complete after about 40% hot reduction, although much of the cast structure was obliterated after half this amount of reduction. The importance of the equi-axial structure in cold-working was confirmed by tests on specially prepared ingots of equi-axial structure.

Columnar crystal aggregates may be completely cold-rolled if the direction of rolling between light passes is changed according to a crystallographic plan provided that the plane of growth of the crystals is in the rolling plane. No indication has been found that any of the peculiarities of zinc in working are due to boundary effects. Failure in zinc at atmospheric or moderate temperatures takes place by characteristic trans-crystalline cracking in which the cracks tend to occur along the basal plane in any one crystal. This form of failure would appear to be limited to a small range of metals and alloys, possibly mainly of the hexagonal crystal type. The effect is greatly intensified by the powerful tendency of zinc to form large columnar crystals, since in an ingot of rectangular section the columnar crystals developed from one mould face have their directions of weakness in the same planes.

The addition of 0·75% cadmium to the zinc produced a small crystal structure but increased the recrystallisation temperature so that complete cold-rolling was no longer possible. The total reduction before cracking started was however, greater when the rolling direction was changed than when rolling was carried out in one direction only.

An account is also given of the conditions under which zinc ingots can be initially rolled during cooling after casting; satisfactory strip was obtainable provided the temperature of the ingot at the commencement of rolling was within the range 350°–100° C., which, when 16 lb. ingots were used, entailed an interval of from 2¼ mins. to 1 hr. after the completion of solidification.

An Aluminium Statue of 1893

In 1893, a statue in aluminium was erected as part of Shaftesbury Memorial in Piccadilly Circus. It appeared to be of considerable interest to ascertain the composition of the metal used and the opportunity was taken when it was dismantled for repairs, and this paper by Professor R. S. Hulton and Dr. R. Seligman was designed to present all possible information on the subject. The results lead the authors to the conclusion that the freedom from serious corrosion of the "Eros" statue, after 38 years' exposure, is due to the fact that it is made of un-alloyed aluminium are recorded. Whether the metal used in 1893 was produced by the old chemical or new electrolytic process is undecided, but the results of analyses of specified examples of old aluminium are reported

Directional Properties in Rolled Brass Strip

The occurrence of directional properties in strip or sheet metal is of considerable interest and practical importance. A number of investigations have been made on directionality, but there still remains much information to be obtained which will not only be of immediate practical use, but which will also help towards a fuller understanding of the subject. The work described in this paper by Dr. Maurice Cook was undertaken to obtain, in the case of brass, information of this kind.

The tensile properties of brass strip have been determined, after progressively increased rolling reductions up to more than 90% in directions parallel, normal and at 45° to the rolling direction. When the rolling reduction has been sufficient to induce a directional effect the greatest strength and least ductility are obtained normal to the rolling direction, while the converse obtains in the rolling direction.

When cold-rolled brass strip is finally annealed, it may show directionality which is revealed both by tensile tests and by the occurrence of ears or waves on the edges of cups cut from the strip. In annealed strip showing directionality, the tensile strength is least and the ductility greatest at 45° to the rolling direction, and it is in this position that ears are formed. The extent to which directionality exists in rolled and annealed strip is largely determined by the conditions of the penultimate and final annealings and by the magnitude of the rolling reduction between these two annealings.

A study of the orientation of twinning planes in rolled and annealed 70 : 30 brass strip showing appreciable directionality in tensile properties and in the tendency to form ears on cups, indicates that the frequency of orientation of the twinning planes is lowest at about 45° to the direction of rolling. The direction of maximum frequency of orientation of twinning planes appears to be fortuitous in strip not showing directionality in other respects.

The Resistance of Some Special Bronzes to Fatigue and Corrosion-Fatigue

This paper by Dr. H. J. Gough and Mr. Sopwith deals with the results of tests carried out on four materials—*viz.*, phosphor bronze (B.S.S. 369 A), aluminium bronze (D.T.D. 160), beryllium bronze (British manufacture), and Superston bronze (D.T.D. 197). In each case, rotating-beam tests have been carried out both in air and in salt-spray. This work was included in the programme of investigation into corrosion-fatigue now in progress at the National Physical Laboratory, on behalf of the Aeronautical Research Committee. The object of these fatigue and corrosion-fatigue tests was to ascertain the suitability of these materials for special aircraft purposes.

The results show that the corrosion-fatigue resistant of the bronzes compares favourably with that of stainless steels, the beryllium bronze in particular having the highest corrosion-fatigue resistance of any material so far investigated by the authors. The fatigue resistance in air of Superston is exceptionally high for a non-ferrous material, but

the material appears to be highly susceptible to stress concentration effects.

Stress-Strain Characteristics of Copper, Silver and Gold

In this paper by Dr. J. McKeown and Dr. O. F. Hudson is described a study of the stress-strain characteristics of gold and silver of a very high degree of purity, and also of two coppers, one oxygen-free but containing a small amount of silver (about 0·003%), the other containing 0·016% oxygen but free from silver, both having little more than traces of other impurities. Stress-strain curves were obtained to determine limit of proportionality, 0·01% proof stress, and Young's modulus. The materials were tested in the fully-softened condition, after slight tensile overstrain (less than 1%) and after definite larger amounts of tensile overstrain (5–15%), and after reheating the overstrained specimens at different temperatures.

It is generally considered that copper in the fully-annealed condition has no elastic limit, and tests show, as was expected, that pure gold and pure silver, when fully annealed, also show no proportionality of stress to strain in any part of the stress-strain diagram.

The elastic properties induced by cold-working were retained in large measure in all three metals after reheating for short periods at moderately elevated temperatures, when the amount of cold-working (tensile overstrain) had been small. Low-temperature annealing, as used in the tests described, did not, however, result in raising the limit of proportionality of pure gold and silver and of oxygen-free and oxygen-containing coppers, to the same extent as in other cases—*e.g.*, other kinds of copper [1, 3]. The tests have shown that, when any of the metals, fine gold, fine silver, oxygen-free and oxygen-containing coppers, has been subjected to a small tensile overstrain, the effect of this small overstrain is evident in the stress-strain characteristics, even after reheating to relatively high temperatures.

The tests have shown that the value of Young's modulus (E) for this oxygen-free copper is decreased by a small (5%) tensile overstrain to $15 \cdot 7 \times 10^6$ lb./in.^{2} (mean value). Larger amounts of overstrain appear to result in a recovery in the value of E; with 15% overstrain the value of E found being $17 \cdot 6 \times 10^6$ lb./in.^{2}. This is in agreement with the results of Kawai's previous work.

Annealing of the overstrained copper tended to restore the value of E lowered by previous overstrain, and by suitable treatment a value of $18 \cdot 2 \times 10^6$ lb./in.^{2} was obtained. Similar effects of reheating after overstrain were found in the cases of fine gold and of fine silver although the raising of the modulus by heat-treatment was less marked than in the case of copper. Gold, which had a value of E of $10 \cdot 3 \times 10^6$ lb./in.^{2} when overstrained 5%, gave $11 \cdot 3 \times 10^6$ lb./in^2. when reheated for ½ hr. at 300° C.

Creep of Lead and Lead Alloys. Part I: Creep of Virgin Lead

A description of the methods used and the results obtained over a period of more than four years on virgin leads of high purity is given in this paper by Dr. J. McKeown. Tensile creep tests have been made on specimens of virgin lead in the form of extruded rod, extruded pipe, and extruded cable-sheath. The tests on rod have been made at room temperature and at 80° C., while the tests on pipe and cable-sheath have been made at room temperature only. The effect on the minimum creep rate of the working produced in flattening cable-sheath and in bending and straightening pipes has been investigated, and this effect has been found to be very marked. It has been shown that results obtained from worked samples may give an erroneous impression of the creep characteristics of the unworked, extruded product.

In the extruded products the effect of initial grain-size on the minimum creep rate has been investigated, and it has been shown that in extruded virgin lead the larger the initial grain-size the higher the resistance to creep at low stresses.

A Study of the Metallography and Mechanical Properties of Lead

The studies described in this paper by Mr. Brinley Jones are concerned mainly with commercially pure lead in the rolled form, although some of the conclusions derived are equally applicable to extruded products. The author refers to the tendencies to structural change in rolled lead at ordinary temperatures, and states that mechanical tests can have little significance unless these changes can be controlled or prevented.

Experiments dealing with the relationship between deformation, grain growth and recrystallisation in "as rolled" structures are described, and it is shown that grain growth develops as a result of the critical straining of very refined "as rolled" structures. Lead of "medium" refinement is found to be immune from grain growth and to be affected only by strains severe enough to cause recrystallisation. The structures which result from grain growth and recrystallisation, respectively, after rolling, are shown to be different in type. In the former, the grains are well defined, infrequently twinned, and often associated with intercrystalline cracking; in the latter they are confused and repeatedly twinned.

Heavily twinned, recrystallised structures have been found, from experience, to be desirable, and reference is made to large-scale experiments dealing with the production, on a commercial basis, of sheets having such structures.

The Control of Composition in the Application of the Debye-Scherrer Method of X-ray Crystal Analysis to the Study of Alloys

The Debye-Scherrer or powder method of X-ray crystal analysis is now used extensively in metallurgy, both for the investigation of crystal structures and the determination of solid solubility curves. On the side of X-ray technique a satisfactory standard of accuracy has been attained provided that certain essential precautions are taken. The defect of the method lies in the uncertainty of the exact composition of the filings comprising the specimen. This point has received comparatively little attention from investigators, and this paper by Dr. Wm. Hume-Rothery and Mr. P. W. Reynolds discusses methods by which these discrepancies may be reduced, since, it is clearly unsatisfactory for the accuracy on the one axis of co-ordinates to be out of all proportion to that on the other.

As a result of this study the authors conclude that where practicable it is desirable to analyse the actual filings from which the representative small sample used in the preparation of the specimen has been sieved. Methods are described for the preparation of perfectly clean filings suitable for accurate chemical analysis. It is shown that in the determination of phase boundaries from lattice spacing measurements of two-phase alloys, misleading results may be obtained if the temperature of the preliminary anneal of the material in lump form is not suitably related to that of the final annealing of the filings.

Alloys of Magnesium. Part IV

This report by Mr. R. J. M. Payne and Dr. J. L. Haughton forms part of the investigation into the constitution and mechanical properties of magnesium alloys which is being conducted at the National Physical Laboratory, under the direction of Dr. C. H. Desch, for the Metallurgy Research Board of the Department of Scientific and Industrial Research. This research was carried out to confirm and to supplement existing information on the constitution of the binary alloys of magnesium and silver.

The form of the liquidus and the values obtained for the eutectic and peritectic temperatures by other workers have been checked in magnesium-silver alloys containing up to

60 weight per cent. of silver. It was found that solid magnesium can hold in solution up to 15 weight per cent. of silver at the eutectic temperature, but less than 1 weight per cent. of silver at 200° C. The alloys should, therefore be capable of precipitation-hardening.

Alloys of Magnesium. Part V

Recent research on magnesium alloys has shown that the mechanical properties of some alloys at elevated temperatures are improved by the addition of small amounts of cerium. The work reported in this paper by Dr. J. L. Haughton and Mr. T. H. Schofield, has been carried out to confirm and possibly supplement information on the constitution of the cerium-manganese alloys and has been extended to alloys containing up to about 40% cerium in order to establish the composition of the eutectic and to confirm the existence of a peritectic reaction. The solid solubility of cerium in magnesium has also been determined.

The eutectic point is found to be at 21% cerium and 590° C. Magnesium dissolves about 1·6% cerium at the eutectic temperature and probably less than 0·15% at 337° C.

The Estimation of Grain-size in the Region Above 10^{-3} cm.

As the ordinary method of grain counting is tedious and cannot as a rule be applied non-destructively, the authors of this paper, Mr. R. A. Stephen and Dr. R. J. Barnes, undertook an investigation into an alternative method of grain-size determination, particularly as the control of grain-size is becoming of more importance in metallurgical practice. The authors critically examine X-ray methods for determining grain sizes above 10^{-3} cm. It is shown that to be generally applied in practice any such method must use the same specimens as are used by the metallurgist for microscopic examination. This necessitates the use of back reflection photographs, except in the case of thin sheets.

A new method for determining a value for average grain-size solely from X-ray results is described. An empirical method too is considered for determining average sizes from a graph. The graph is derived from plotting spots on a given (*hkl*) reflection against the grain-size of standard specimens.

International Association for Testing Materials

International Congress in London

The Congress of the International Association for Testing Materials, to be held in London on April 19–24, 1937, is likely to be of great practical value to all in this country who are makers and users of the materials concerned, in addition to being of interest to those engaged in their scientific study. This Association is representative of the national testing associations or equivalent organisations in about twenty-five of the leading industrial countries of the world; it is controlled by a permanent committee composed of representatives of these countries. The function of the Association is to secure international co-operation and an exchange of views, experience and knowledge in regard to materials and their testing. With this object, international congresses are organised at intervals of from three to five years, the last congress being held at Zurich in 1931.

The subjects for discussion at the Congress have been divided into the following four groups, for each of which a Group President has assumed responsibility :—

Group A, "*Metals.*"—(President : Professor C. Benedicks, Sweden. Vice-President : Dr. H. J. Gough, F.R.S., Great Britain). Approximate number of Papers, 77.

(1) Behaviour of metals (mechanical and chemical) as dependent upon temperature, particularly in regard to high temperatures (25 Papers), (2) Progress of metallography (25 Papers), (3) Light metals and their alloys (14 Papers), and (4) Wear and machinability (13 Papers).

Group B, "*Inorganic Materials.*"—(President : Professor E. Suenson, Denmark. Vice-President : Direktor P. F. van der Wallen, Holland). Approximate number of Papers, 63.

(1) Concrete and reinforced concrete (43 Papers), (2) Erosion and corrosion of natural and artificial stone (5 Papers) and (3) Methods of testing ceramic bodies (15 Papers).

Group C, "*Organic Materials.*"—(President : Dr.-Ing. R. Barta, Czechoslovakia. Vice-President : Professor J. O. Roos-af-Hjelmsäter, Sweden). Approximate number of Papers, 45.

(1) Textiles (9 Papers), (2) Wood cellulose (10 Papers), (3) Timber preservation (10 Papers), (4) Ageing of organic materials (9 Papers), and (5) Colours and Varnishes (7 Papers).

Group D, "*Subjects of General Importance.*"—(President : Professor H. Rabozée, Belgium. Vice-President : Professor Dr. M. Rovs, Switzerland). Approximate number of Papers, 25.

(1) Relation between the results of laboratory tests and behaviour in use and service (6 Papers), (2) The bearing of recent advances in physics and chemistry on the knowledge of materials (7 Papers), and (3) The properties of materials for the thermal and acoustic insulation of buildings (12 Papers).

It will be noted that over two hundred papers are to be presented at the various technical sessions; these are by leading authorities from about twenty different countries. It is noteworthy that the papers have been written in summary form with the object of providing in as short a space as possible authoritative and comprehensive reports on the progress made in each subject during the last five years. In addition to the technical sessions extensive arrangements have been made in the programme for works visits, excursions and social functions.

This is the first occasion on which a Congress of this Association has been held in London, and it is unlikely that another will be held here for many years; it is natural, therefore, that the British Reception and Organising Committee, which has undertaken the organisation of this Congress, should be particularly anxious to ensure that the British membership shall be representative and numerous. The occasion is unique, and it is confidently expected that the opportunity will be taken to render all possible support. Full information is available from the Hon. Secretary of the Congress, Mr. K. Headlam-Morley, 28, Victoria Street, London, S.W. 1.

Silver Production in Canada, 1936

Silver production totalled 18,089,000 fine oz., valued at $8,164,000, as compared with 16,618,558 fine oz., worth $10,767,148 in 1935. This is an increase of 9% in quantity, but a decrease of 24% in total value. The average price of silver in Canada during 1936 was 45·1319 cents per fine oz., as against 64·7899 cents in 1935. It is interesting to note that the silver produced from nickel-copper ores of Sudbury area in 1936 was greater than the entire recovery from cobalt-silver ores which were, at one time, the principal Canadian source of this metal. British Columbia mines, however, account for 53% of the Canadian total. The famous Sullivan silver-lead-zinc mine of that province is by far the largest single source of silver in Canada.

Gas Burners for Heat-Treatment Furnaces

Efficient burners for the use of blast-furnace, coke-oven and producer gases, provide a problem for the iron and steel works. In this article are given specific installations from which good results are being obtained.

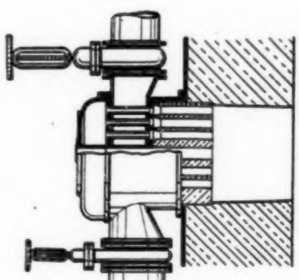
IN operating gas-fired heat-treatment furnaces of all kinds in the iron and steel industries the best results can only be obtained by using an efficient design of turbulent burner.

This separate valve control of the gas and the air is just as essential as rapid and intimate mixing of the gas and air before and during combustion, which must also be supplied at low pressures. In addition, a good design of burner is not affected by the heat, can be easily cleaned, and operates with a short "stable" flame. In this connection the latest scientific principles are well represented by the "Gako" turbulent burners supplied by Liptak Furnace Arches Ltd. It is appreciated that no design of burner will give maximum efficiency for every condition, covering all types and qualities of gas, designs and sizes of furnace setting, and rates of combustion. For this reason a range of burners is available, suitable for every type of gaseous fuel, including producer gas, blast-furnace gas, coke-oven gas and town's gas, but the basic principles are the same in each case, that is, low-pressure operation, generally 2 to 4 in. W.G., independent valve control of the gas and air supply, and the passage of the gas, and in many of the designs also of the air, through the burner in alternate thin layers or streams, which are given a twisting or whirling motion by means of spiral guides and passages. Also the gas may be hot or cold, and dirty or clean, whilst, the air can be cold or preheated and supplied either at atmospheric pressure or slightly higher.

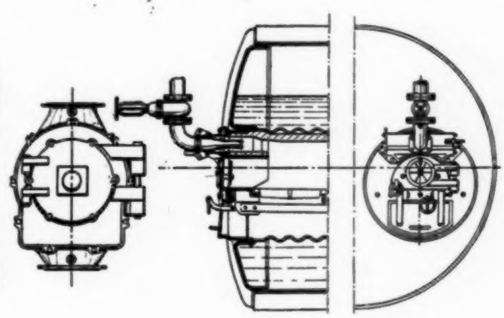
For example, the exact design of the burner used depends on whether the operating conditions involve continuous exposure to radiant heat from the furnace wall or the material, as with many types of heat-treatment furnaces in the iron and steel industries. One standard design for these conditions is the "multiple jet," having a separate series of jets or tubes contained within a refractory block projecting slightly into the furnace, these jets having their own supply of gas and low-pressure air in the correct proportion, each of which is split up into thin streams and given a whirling motion.

For smaller settings a simple type of burner is available, with a valve-controlled low-pressure gas supply pipe at the centre, so arranged, on the usual lines, that the gas is split up into a number of streams, whilst in this case the air is drawn in by shutter-controlled openings in the casing, under atmospheric pressure, mixing direct with the gas streams. A number of the designs also operate normally with the gas and low-pressure air under forced draught supplied through a pipe from a fan or other source, but the latter can be shut off and the front of the casing removed so that the burner operates with atmospheric pressure air taken in direct, the only difference being that the gas consumption is reduced in proportion to the lesser volume of air passing. If desired certain of the burners can have the gas and pressure air supply valves connected by linkwork after adjustment, so that any alteration given to the gas supply according to the furnace demands results automatically in the equivalent correct alteration in the air. Another important point is the wide range of sizes available, from 300 cu. ft. of gas per burner per hour up to 500,000 cu. ft. per hour.

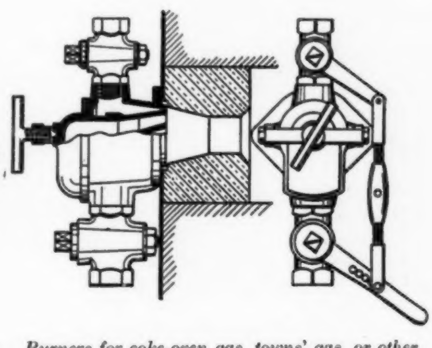
Burners can also be combined with electrically-operated automatic temperature control equipment, including a small self-contained motor. In general, all the different burners of this make operate at extremely high efficiency, giving complete combustion of the gas with little excess air, and maximum CO_2, while they can instantly be adjusted to give either an oxidising or a reducing atmosphere. The flame also is short, soft, and globular, with no sign of "cutting" action, as with high-pressure burners, because of the rapid completion of the combustion due to the effective gas and air mixing and the low pressure, which means uniform temperature in the largest setting operating with a row of burners.



Multi-jet type of rotary burner for large combustion chambers such as metallurgical furnaces with a refractory protecting block and pressure air supply.



Burners for any type of gas used as auxiliary to hand-firing, with solid fuel for operating "Lancashire" and similar types of boilers.



Burners for coke-oven gas, towns' gas, or other gas and pressure air supply, the gas and air control valves being connected together by linkwork.

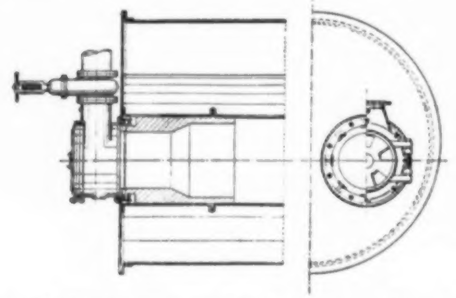
The maintenance also is negligible, because of the robust construction and the absence of moving parts, while another feature is easy accessibility, inspection and cleaning, all that is necessary being to open a hinged door. With regard to foundry work an interesting installation of "Gako" burners of the forced-draught air supply type is operating at a well-known motor-car works in the South of England, fitted on a rotary furnace.

An interesting installation of burners of the forced-air supply type, using coke-oven gas, is operating a series of new air jacketed forging furnaces at a well-known iron and steel works in England. Each furnace has two burners representing a total consumption of 3,000-3,500 cu. ft. of coke-oven gas per hour, whilst the air is supplied with preheated air from the furnace jackets. Also, the coke-oven gas supply from the firm's by-product oven plant is at a high-pressure of 5 lb. per sq. in., which is reduced to about 3 in. W.G. before reaching the burners, by a special valve.

A temperature of 2,462-2,552° F. (1,350-1,400° C.) is easily maintained with very accurate control. In this works also large "Gako" burners with a capacity of 25,000 cu. ft. of coke-oven gas per hour with preheated air at 400° F.

(200° C.) are operating rotary smelting furnaces for malleable cast iron, which is poured at 3,002° F. (1,650° C.).

At another well-known iron and steel works in the South Wales area 20 of these forced-draught burners are fitted in a tube heating oven, using high-pressure blue water gas. The latter is reduced to a few inches W.G. for the burners, and the oven is operated at only 450° F. (232° C.), which has to be maintained with great accuracy becasue of subsequent treatment with bitumen to prevent corrosion.



A rotary flow burner for "Lancashire" boiler burning blast-furnace gas, coke-oven gas, or other gas with air at atmospheric pressure.

All the burners are fixed in a row along one of the side walls of the furnaces in which the tubes, up to 25 ft. long and 45 in. diameter are caused to rotate. Interesting also with regard to this particular installation is the fact that, although each of the 20 burners has its own separate valve, for gas and air supply, these are not used in normal working regulation, being effected by valves on one gas and one air main connecting to all the burners.

Catalogues and Other Publications

We have received a copy of a small tools catalogue, published by the English Steel Corporation, Ltd., Vickers Works, Sheffield, which is a complete compendium of the small tools manufactured by this firm at the Openshaw and Sheffield works and which supersedes the sectional booklets previously issued. This book of 238 pages is very comprehensive in character; not only will it facilitate the ordering of tools, but it will prove handy for reference. It carries a useful index, is well bound, and will be invaluable to users and potential users of the comprehensive range of small tools described.

Edgar Allen and Co., Ltd., have sent us copies of the latest editions of their Carbon Tool Steel and High Speed Steel booklets. The heat-treatments and other practical working details of the steels mentioned are brought up to date and the two booklets form a compendium to the proper use, care and treatment of a range of tool steels covering many and varied purposes. Those interested should write Imperial Steel Works, Sheffield, 9, for copies.

Burdon Furnace Company has sent us a booklet which gives information regarding the Burdon Oil Gas System. This system is claimed to economically satisfy any demands that may be made upon it, and the booklet is profusely illustrated with furnaces in which the system is being applied industrially. Copies of the booklet are available from the registered office of the Company, 36, West Princes Street, Glasgow, C. 4.

We have received a copy of the 1937 booklet on "Vitreosil," which indicates the rapid progress in the production of Vitreosil pure fused quartz and silica ware and its applications to the chemical, electrical, and other manufacturing industries, as well as in domestic life. It is no exaggeration to say that in many laboratory operations, especially those where heat or acids are involved, Vitreosil has almost entirely replaced other materials, and this booklet will be found particularly interesting and informative. Copies may be obtained from the Thermal Syndicate, Ltd., Wallsend-on-Tyne, England.

The properties, manufacture and application of Firth-Vickers rust acid and heat-resisting steel castings are given in a booklet recently issued by Firth-Vickers Stainless Steels, Ltd., Staybrite Works, Sheffield, 9. The information given is supplemented by admirable illustrations showing some applications of the various steels mentioned.

Correspondence

Cold-Rolling Deep-Drawing Steels

The Editor, METALLURGIA.

Sir,—After reading Part 3 of my article on "Cold-Rolling Deep-Drawing Steel," published in your February issue, I much regret that inadvertently mention of the source of valuable information relating to the mechanism of deformation and the effects of annealing has been omitted. All this information together with a number of illustrations, were obtained from a paper by Dr. L. B. Pfeil to the Swansea Technical College Metallurgical Society, in 1928, on the Mechanism of Deformation and Annealing of Bright Steel for Tinplate Manufacture.

Perhaps you would be good enough to bring this to the notice of your readers at your earliest convenience. At the same time may I take this opportunity of expressing my regret for the omission and to emphasise that it was quite an oversight on my part.

Feb. 26, 1937. J. L. TURNER.

Forthcoming Meetings

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

April 1. "Modern Methods of Alloy Steel Analysis," by B. Bagshawe.

LONDON SECTION.

April 8. Annual General Meeting and Open Discussion.

SWANSEA SECTION.

April 13. "Metallic Wear," by H. W. Brownsdon, M.Sc., Ph.D.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Mar. 23. "Some Aspects of Material Handling," by J. B. Mavor.

April 6. Annual General Meeting.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

April 2. Annual General Meeting. Short Paper Competition.

EAST MIDLANDS BRANCH.

Mar. 20. Annual General Meeting. Members' Problems (at Loughborough).

LINCOLNSHIRE SECTION.

Mar. 20. Students' Papers.

April 3. Annual General Meeting.

LANCASHIRE BRANCH.

April 3. I—Annual General Meeting.

II—Presentation of Reports of Sub-Committees of the Technical Committee :—

(a) Recommendations of the Non-Ferrous Sub-Committee for Two Leaded Gunmetals.

(b) Dimensional Tolerances for Castings, with particular reference to Malleable Cast Iron.

LONDON BRANCH.

April 7. Annual General Meeting. Short Paper Competition.

MIDDLESBROUGH BRANCH.

April 16. Visit to the Coke Oven Plant, Messrs. Dorman Long and Co., Ltd.

NEWCASTLE-ON-TYNE BRANCH.

Mar. 27. I. Annual General Meeting.

II. Report upon the work of the Technical Com-Committee by F. B. Ellis and G. Elston.

SHEFFIELD BRANCH.

April 1. I. Annual General Meeting.

II. "Pig Iron," by R. C. Tucker, M.A.

WALES AND MONMOUTH BRANCH.

Mar. 20. Annual General Meeting (at Cardiff).

WEST RIDING OF YORKSHIRE BRANCH.

April 10. Open Discussion.

Vickers, Ltd., announce that General the Hon. Sir Herbert A. Lawrence, G.C.B., has expressed his desire to be relieved of his duties as chairman of the company from the conclusion of the forthcoming annual general meeting. Thereafter General Lawrence will retain his seat on the Board for the time being. Mr. A. A. Jamieson, who has been a member of the Board for over eight years, will succeed Sir Herbert Lawrence as chairman of the company.

The International Electro-Deposition Conference

Many well-known experts from countries in which electro-deposition has made most immediate progress were present at this Conference, which was organised by the Electro-depositors' Society, and held at British Industries House early this month. A large number of papers were presented. Here it is only possible to refer briefly to a few of these papers.

ELECTRO-DEPOSITION has made very considerable progre s in the course of the last ten to 15 years. A greater degree of development has probably occurred over this short period than throughout the whole of the previous history of electro-deposition. Much of this progress is due to intensive research work carried out by independent workers, chiefly in universities and technical colleges, large industrial corporations, and supply houses interested in the electro-deposition industry and Government research establishments.

This country has been well to the fore in the development of electro-deposition work, both on the research side and also in industrial development. Other countries which have contributed considerable work in this field are the United States, France, Germany, Italy, Russia and Holland. It is therefore particularly appropriate that this first international conference should be sponsored by the Electro-depositors' Technical Society in this country, and it is very gratifying that representatives of all these other countries which have helped forward the development of the subject should have been present on this occasion.

Formally opening the conference, Lord Melchett recalled the occasion two years ago, on which he opened the first public exhibition relating exclusively to electro-deposition at the Science Museum. The present occasion, he said, was one of even greater significance, and the Council of the Society could justly pride itself on the organisation of an international conference which was the first of its kind, and in which experts from France, Germany, America and the U.S.S.R. were participating.

In welcoming the foreign visitors to the conference, Lord Melchett expressed gratification that so many well-known experts from countries in which electro-deposition had made most immediate progress should have made it their business to be present, and expressed the hope that their stay in this country would be a happy and useful one.

Electroplating Practice

Among the many papers presented at this conference, it is appropriate to refer briefly to four papers which deal with electroplating practice in Britain, France, Germany, and the United States respectively. It is probably true that the interchange of information and ideas is so complete that any sharp line of demarcation between methods in use in any country and those favoured in another has disappeared, and the only difference which remains is one of magnitude of operation and equipment. On the other hand, economic problems have a habit of cropping up and creating differences in actual practice.

In British practice, according to a paper by Mr. E. J. Dobbs, nickel must be accorded premier place in the list of deposited metals from the point of view of tonnage alone, and a great increase in the use of the metal may be ascribed to the advent of chromium plating. The solutions favoured are the single-salt solutions containing nickel chloride to provide for anode corrosion and boric acid as the buffering agent. They are usually worked warm, at temperatures of 32°–40° C., and are invariably agitated by means of water-washed compressed air as an aid against pitting. The solutions are continuously filtered by means of air injectors and lifts, using felt filter bags fashioned in the shape of a sugar loaf and held in position in conical lead funnels. The vats used are generally of wood, lead-lined, and fitted with a further loose lining of reinforced glass; rubber-lined tanks, both of wood and iron, are also being used.

The nickel solution is normally worked at pH values 5–2–6·0 (colorimetric) and at current densities of 20–24 amps. per sq. ft. Occasionally, instances are met where current densities as high as 40 amps. per sq. ft. are being used, but the practice is far from general. The concentration of the solution is usually 50–55 g. per litre with about 12–15 g. per litre boric acid and 25–30 g. per litre nickel chloride.

In the deposition of chromium the general practice in Great Britain is to prefer solutions of much greater concentrations of chromic acid than is used abroad, and to work such solutions at lower current densities. The difference in practice in regard to cadmium plating between this country and abroad may be summarised in bright plating. Firms plating cadmium seem content to deposit the matte or dull type of coating, and, if a bright finish is required, to bright dip the articles. In the deposition of tin, the majority of tin solutions in Great Britain are composed of stannous chloride, brown potash, and a trace of glue. The solution is easy to work, simple to correct, and cheap in replacement.

Nickelplating has progressed in France as in other countries. According to a paper by M. Ballay, the improvements realised in the last ten years have been very considerable, affecting the quality of the deposit, its adhesion, thickness, and texture. In France, as elsewhere, the development of chromium-plating has been a new incentive to the improvement and development of nickelplating, and during the past two or three years particularly, applications of thick nickelplating have considerably increased in number. Further, there still is a very large number of potential applications.

French technique, however, shows certain individual characteristics. Since 1929, for instance, rapid plating has been practised on a commercial scale, with current densities of 5–10 amp. per sq. dm. About the same time there was introduced a special type of equipment or chain of tanks condensed in a small space and allowing without any difficulty good electrical contacts such as are necessary for the use of high current densities and for regular mass production, together with a very accurate control of the time required for the various operations. It seems that bright plating has not attracted so much attention in France as in other countries. This is probably due to the fact that bright plating has been in regular production in France for quite a long time; baths working cold at a very low current density were introduced in 1904, and subsequently the temperature of the bath has been raised with a view to reducing the time of operation. The author discusses bright nickelplating with special reference to a process which has been in use in France for some years, and to a new process which employs egg albumen as the brightening agent.

In Germany a shortage of nickel exists, but their is a sufficient supply of nickel sulphate of German manufacture available. According to a paper by Richard Springer, German platers have adjusted themselves to this condition

of working their nickel solutions with insoluble anodes, replenishing the metal, and adjusting the acidity by the addition of nickel carbonate. Out of this practice developed the improved method of renickeling nickel anodes in separate vats. Nickel is deposited on lead strips in this manner, and these strips are then used as anodes in normal nickel vats.

German high efficiency tinning baths are characterised by the fact that they are built up on aromatic sulphonic acids and their salts and allow the production of bright deposits also at high-current densities. It must, however, be admitted that, in spite of some contrary statements, the problem of bright tinplating has not yet been entirely solved and that there is no tinning bath producing absolutely bright deposits. Tinplate is being produced in Germany by electrolytic processes, but the resulting brilliance is only obtained by a subsequent treatment of the plate, mostly by subsequent rolling. 90% of all cadmium baths are now producing bright deposits.

Electroplating of aluminium has gained special importance in Germany, particularly in recent years. Until some years ago, the success of the nickel and chromium plating of aluminium was more or less accidental. This question has been studied more closely in the last two years, and it can be said that it is now possible in Germany to nickel and chromium plate almost every aluminium alloy. Before electroplating, the aluminium or aluminium alloy is subjected to a preliminary dipping treatment in which a very thin film of a nobler metal—for instance, zinc—is deposited on the base metal. The article thus treated is then cyanide-copper plated for about 10–20 mins., and is then ready for any further treatment. The treatment known as the Ballay process, consisting of dipping in an iron dip, has been partly abandoned in Germany. By a further and somewhat complicated process, aluminium is first anodically oxidised, the anodic film is then wholly or partially removed, and the article is then plated in the usual manner.

The shortage of non-ferrous metals in Germany has led to the extended use of bakelite, celluloid, and similar materials instead of metal in the manufacture of numerous articles, such as door handles and fittings, lighting fixtures, ash trays, cigarette cases etc. This has opened a new field of activity for the plating industry by plating non-metallic surfaces. A new and improved process has been developed which ensures perfect adhesion of the metal deposits. Plating costs are practically the same as they are for plating on metal, as the pressed articles need no polishing before plating. The plated articles are hardly distinguishable in appearance from solid metal. Many of these developments are not mere temporary measures; it is to be assumed that many of the materials which are now introduced in Germany as substitutes will be retained on account of their cheapness, suitability, and good appearance, even when sufficient metal supplies are again available.

The Tinning of Steel Strip by Electro-Deposition.

Quite recently, efforts have been made to apply electro-deposition as a means of coating steel with tin as an alternative to hot-dipping and the results of some experimental work are presented in two papers. The first, by Messrs. D. J. Macnaughtan, W. H. Tait, and S. Baier, deals with the electro-deposition and polishing of thin coatings of tin on steel; the second, by Messrs. D. J. Macnaughtan and J. C. Prytharch, deals with the effect of deformation on the protective value of hot-dipped and electro-deposited tin coatings on steel. It was desired to obtain material for comparative tests of the quality of different tin coatings produced under known conditions.

Continuous plating of strip 2 in. wide was carried out in: (1) Alkaline stannate solution with (*a*) insoluble anodes, using a method of regeneration of the tin content of the solution previously described; (*b*) with tin anodes using the method recently described by Hansel, which ensures that tin enters the solution entirely as stannic ions. (2) A typical acid tin solution consisting of stannous sulphate, sulphuric acid, cresolsulphonic acid, with additions of glue and other organic addition agents.

Satisfactory plating of strip was obtained by all these methods during the relatively short period of the trials. The acid bath, however, presented important advantages over the alkaline bath—*e.g.*, (*a*) no heating of the solution required as in the case of the alkaline bath; (*b*) lower bath voltage; (*c*) more than double the rate of deposition for the same cathode current density.

It appeared that in the acid bath, speeds of electro-tinning comparable with those used for hot-tinning are feasible. But whether the process is likely to be fully satisfactory under industrial conditions depends upon the appearance and quality of the coatings. With reference to appearance, the electro-deposited coatings were not comparable in brightness with coatings produced by hot-tinning. Smooth matte deposits were obtained in the alkaline solution, but in the acid solution they varied from coarse matte to a smooth matte, and in special cases were semi-bright, according to the amount of organic addition agent present in the solution. Such coatings require some form of polishing or smoothing process. In order to obtain reliable comparative data, an apparatus was devised which allowed of polishing under controlled conditions.

Porosity tests were carried out to determine the protective values of the various types of tin coatings from which it would appear that the following types of coating are unsuitable—viz., (*a*) "Alkaline" tin deposits; (*b*) bright "acid" tin deposits; (*c*) rough matte "acid" tin deposits. This leaves as an alternative to hot-dipped tin coatings the smooth matte "acid" tin coating and the composite coating produced by electro-deposition of tin from the alkaline bath on a hot-dipped tin coating.

From the technical point of view, one of the chief problems in the production of the former type of coating will be the maintenance of the conditions that ensure the formation of deposits of smooth matte ductile tin. This will involve careful control, since the structure of the coating is largely dependent upon the presence of suitable amounts of organic agents in the acid bath. The production of a composite tin coating by the super-deposition of electro-deposited tin on a hot-dipped or fused tin coating involves a number of special complications.

It remains, therefore, to be determined whether the processes involved in producing satisfactory ductile coatings of tin by electro-deposition will prove as economic as by the hot-dipping process. It has to be borne in mind that the latter process is likely to be improved and may be made continuous for the coating of wide steel strip.

The Welding and Cutting Year Book

Since the last issue of this Year Book, welding in all its phases has extended very considerably. Some indication of the importance with which welding is now regarded was given by "Symposium on the Welding of Iron and Steel," organised by the Iron and Steel Institute, held in May last year. The first session attracted an audience of over one thousand persons. Fabrication by means of the various welding processes has undoubtedly made remarkable progress during the last year or so, and this book gives information regarding the more recent developments of the processes. All the various processes are discussed in an interesting and informative manner, and all who are engaged in welding, or who desire to explore the possibilities of one of the processes, should obtain a copy of this useful Year Book.

Edited by Cyril Helsby, Conrad W. Hamann and Dipl. Ing. Felix J. Samuely; published by the Temsbank Publishing Co., Ltd., 12, Whitehall, London, S.W. 1. Price, 5/- net.

Research in Relation to the Motor-Vehicle

Materials with Special Reference to Steel

In a symposium recently presented at a joint meeting of several technical societies, under the auspices of the Institution of Automobile Engineers, research in relation to the motor-vehicle was discussed in three sections—The Motor-Vehicle ; Fuels and Lubricants ; and Materials. The section on materials, presented by Dr. T. Swinden, deals particularly with steels, and is given here in an abridged form.

IN the design of materials for automobile construction, there is the continual striving for improved performance accompanied by the most strenuous efforts to reduce costs, an ever-present two-fold problem, developed to a degree probably unrivalled in any other industry. Dr. Swindon indicates the trend of development of steels for the most important parts of the motor-car, and considers first, the crankshaft.

Crankshafts

The range of qualities classified as crankshaft material is very considerable. In the recommendations compiled by the Technical Committee of the S.M.M.T., it is quoted as a "typical" use for seven steels ranging from 0·40%, carbon, 1·0% manganese, having 35 tons per sq. in. minimum tensile to nickel-chromium-molybdenum steel having 110 tons per sq. in. minimum tensile. There appears to be a definite tendency to go over from the plain carbon and 1% nickel steel, giving 40 to 50 tons per sq. in. tensile, to manganese-molybdenum steels having 50 to 65 tons per sq. in. tensile, which there still remains a large use for nickel-chromium and nickel-chromium-molybdenum steels with tensiles in the 55 to 75 tons range. A selection of actual tests, regarded as typical of those to be obtained from the seven steels mentioned, are given in the paper, together with a selection of tests of some other steels, which have also been supplied for making automobile crankshafts, and which are reproduced in Table II. All the tests listed are of open-hearth steel with the exception of the 3% chromium-molydenum, which is high-frequency electric quality.

The quality of steel used for crankshafts appears to be judged by tensile strength as related to fatigue strength and wear resistance, together with adequate toughness. On the other hand, it is known that the cast crankshaft, having a tensile strength of only about 45 tons per sq. in. and practically no toughness, as judged by the impact tests, is behaving satisfactorily, at least in certain engines. The explanations so far given for the success of the cast crankshaft, in spite of its shortcomings as judged by tensile and impact strength, are based on damping capacity as related to fatigue resistance, and reduced wear on crankpins and journals. When a full explanation is available, it will throw some light on the true significance of the tests at present applied to crankshafts and other materials. The problem of wearing testing is still an elusive one, however, the structure of the cast crankshaft material should be well suited to resist wear, although the hardness is only of the order of 280 Brinell.

Next to maximum resistance to fatigue, wear on the crankpins and journals is no doubt regarded as the most important factor requiring improvement. The result of the research going on concerning the wear of a number of crankshaft materials running in lead-bronze bearings is awaited with keen interest. Meanwhile, efforts to improve wear resistance, particularly in oil and high-duty petrol engines have taken the form of nitrogen hardening, chromium plating, casehardening (including cyaniding and Chapmanizing), flame-hardening, and "Tocco" hardening.

Valves

It is noted that in the S.M.M.T. list only one steel is included, namely, silicon-chrome, as normally supplied to D.T.D. 13 B. This appears to give general satisfaction for exhaust valves, but attention is directed to two other types of exhaust valve steel in use where higher temperatures and generally more severe conditions of service obtain. A summary of some tests on these three types of steel is given and is reproduced in Table V.

Hard-drawn carbon steel wire to D.T.D. 5 A is generally employed for valve springs, and numerous researches have indicated the necessity of paying special attention to freedom from surface decarbonization and perfection of surface as regards freedom from irregularities and defects. The

TABLE II.—CRANKSHAFT STEELS.

—	Type of Steel.							
	0·50 to 0·55% C.	0·4% C., 0·5% Ni.	1% Ni-Mn-Mo.	Mn-Mo.	Cr-Mo.	3·5% Ni.	3% Ni-Cr-CH.	3% Cr-Mo.
ANALYSES (actual)—								
Carbon, %	0·52	0·42	0·35	0·39	0·37	0·39	0·13	0·29
Manganese, %	0·69	0·69	1·18	1·58	0·52	0·66	0·39	0·51
Nickel, %	—	0·51	1·01	—	—	3·32	3·28	—
Chromium, %	—	0·06	0·15	—	0·93	0·13	1·01	3·22
Molybdenum, %	—	—	0·28	0·27	0·23	—	—	0·58
GRAIN SIZE	7	7	7	6 to 7	7 to 8	7	7	8
MECHANICAL TESTS—								
Dimensions of test section, diameter in inches	1⅛	2½	2½	2½	2½	2½	1⅛	3½
Heat-treatment, °C.	O.H. 830 T. 580	O.H. 830 T. 650	O.H. 830 T. 650	O.H. 830 T. 630	O.H. 830 T. 600	O.H. 830 T. 570	O.Q. 800	O.H. 900 T. 600
Maximum stress, tons per sq. in.	58·2	44·9	58·0	56·0	56·3	55.2	70.3	72·1
Yield-point, tons per sq. in.	39·1	31·0	49·2	46·0	48·3	46·5	62·0	66·3
Elongation % on 2 in.	20·5	27·0	20·0	23·0	21·0	22·5	17.0	19.0
Reduction of area, %	47·2	63·6	61·6	61·6	59·2	57·2	57·2	63·6
Average Izod impact figure, ft.-lb.	32	68	69	80	72	65	46	66

alternative use of hardened and tempered carbon steel wire and the relative merits of these qualities as compared with heat-treated silico-manganese and chrome-vanadium steel wire continue to receive attention.

TABLE V.

VALVE STEELS.

Type.	—	D.T.D. 13 B.	D.T.D. 49 B.	D.T.B. 282.
Analysis, %	Carbon	0·45	0·45	0·45
	Silicon	3·5	1·25	1·25
	Nickel	—	14·0	8·0
	Chromium	8·0	14·0	18·0
	Tungsten	—	2·0	2·0
Hot tensiles ($\frac{1}{24}$ in. per min.), ton per sq. in..	700° C.	6·2	23·6	24·9
	800° C.	3·5	12·2	14·9
	900° C.	—	7·2	8·4
		Gain in Weight in Mg. per Sq. Cm. of Area.		
Resistance to scaling heated in electric muffle furnace for 96 hours).	900° C.	0·56	1·72	0·03
	1,000° C.	7·51	68·7	1·60
	1,100° C.	209·0	291·0	3·27
		Loss in Weight in Mg. per Sq. Cm. of Area.		
Attack by leaded fuels Polished cylinders immersed in a mixture of equimolecular proportions of PbO and $PbBr_2$, for 6 hours.	750° C.	44·5	81·4	69·7
	850° C.	73·9	104·6	87·6

Gears

There is considerable diversity of opinion concerning steel for gears, eight types being listed in the S.M.M.T. compilation. The steels normally employed for gear-box gears can be divided into three categories: air-hardening nickel-chromium and nickel-chromium-molybdenum steels; alloy case-hardening steels; and direct oil-hardening steels. The latter comprise chromium, nickel-chromium and nickel-chromium-molybdenum qualities with or without a surface hardening treatment. There has been a tendency in the case of these gears to revert from case-hardening to direct-hardening steel quenched from a salt bath containing a carburizing agent such as cyanide.

For crown wheels, bevel pinions and differential gears, 5% nickel case-hardening steel is probably the most popular steel, while 3½% nickel and nickel-chromium steels are also used. An effort has been made to provide an alternative to the 5% nickel steel in the form of a low nickel-chromium steel which is at present undergoing test. Table VII indicates the core properties of this steel from tests made on 1⅛ in. dia. bar after four hours at 900° to 920° C. furnace-cooled and subsequently quenched as stated. As compared with 5% nickel, this steel is less sensitive to mass effect and allows greater latitude in heat-treatment.

TABLE VII.

Treatment.	Maximum Stress, Tons per Sq. In.	Yield-point, Tons per Sq. In.	Elongation % on 2 in.	Reduction of Area, %.	Izod Impact, Ft.-lb.
O.Q. 850° C. B	58·6	49·8	23·5	54·8	66
O.Q. 780° C. .	60·8	52·0	22·0	54·8	64

Considerable attention is being given to reports emanating from the United States concerning a fine-grain nickel-molybdenum case-hardening steel of the S.A.E. 4615 type, which contains approximately 0·15% carbon, 1·85% nickel, 0·25% molybdenum, with particular reference to the results being obtained on this steel when quenched direct from the carburizing temperature.

Machinability

The problem of devising a "machinability index" has engaged Dr. Swinden's attention for many years. The conflicting factors involved seem to make it impossible to obtain any single value which will reflect accurately a comprehensive machinability factor, and this is the considered view of all those who have made exhaustive researches on the subject. It is, however, generally agreed that the nickel-bearing steels are not so easily machined as the manganese, manganese-molybdenum, and chromium-molybdenum steels of similar Brinell hardness. After examining in detail three accepted methods of testing, Dr. Swinden has succeeded in getting consistent and reproducible values which are in line with general machine-shop experience, so far as turning is concerned, and the work is proceeding to investigate screw cutting and drilling. This refers to medium and high-tensile steels. Rapid machining (free-cutting) soft steels are tested as a routine matter of production.

Pig-iron Duty Dropped

In view of the continued demand, the Import Duties Advisory Committee reported in a recent announcement that there were difficulties in obtaining adequate supplies of pig iron and the scrap used for the manufacture of iron and steel, with the result that the steel industry is being hampered. It is explained that the present duty of 33⅓% and the present level of world prices makes it unprofitable to import pig iron from foreign sources.

The Committee are satisfied that the steps being taken by the British Iron and Steel Federation to ensure that so far as possible supplies are adequate and that prices are not unreasonably increased, will be facilitated by the removal of this duty pending the developments which are taking place to increase the supplies from home and Empire sources.

With regard to the reduction in duty on certain iron and steel products, the Committee report that the striking increase in the demand for steel in this country has been paralleled by a similar growth in other countries, with the result that for the time being the world demand tends to outrun supply.

30-Ton Steel Casting

The English Steel Corporation, Ltd., recently completed a big steel casting at its Grimesthorpe foundry, Sheffield, to the order of Lamberton and Co., Coatbridge, Scotland. The casting is claimed to be one of the largest cast-steel mill housings ever produced in England, and weighs nearly 80 tons. It has been one of the numerous heavy jobs of a commercial type which is providing the basis of the activity in the Sheffield steel trades.

New Oil-from-Coal Plant for South Wales

Arrangements have been made for the establishment of a large "Coalite" plant in South Wales. The new works will comprise a carbonising plant similar to that erected at Bolsover last year and capable of treating 500 to 750 tons of coal per day. In addition, there will be a coal-oil distillation plant arranged for the production of aviation petrol, Diesel oil, fuel oil, creosote, and the other usual derivatives. Further, there will be a large plant for the manufacture of tar acids and other chemical products, for which a considerable export market has been established. The "Coalite" smokeless fuel produced will be distributed mainly in the West and South-West of England, in which areas there has always been a large demand which the company have been unable to satisfy.

One of the great advantages of the scheme is that it will enable South Wales coal to be rendered suitable for the house-coal trade and place at the disposal of the West of England the same facilities for securing supplies of smokeless fuel as are now enjoyed in other districts. The new scheme will be owned and operated by Low Temperature Carbonisation, Ltd., through a new subsidiary company, the South Wales Coalite Co., Ltd. The board and management will be the same, with Colonel W. A. Bristow as chairman and managing director, and Sir David Llewellyn has also kindly consented to join the board, thereby bringing to the company the benefit of his great experience of the mining industry in South Wales.

Recent Developments in Materials, Tools and Equipment

THE BROWN OPTIMATIC SYSTEM

A New Self-Balancing Automatic Optical Pyrometer

A NEW optical pyrometer has been developed, known as the " Optimatic System," which operates entirely without the aid of the human eye. Its purpose is to measure the surface temperatures of hot materials instantaneously and to indicate or record automatically, on a graphic instrument, all variations of temperature during the period that the hot body is viewed.

This system has been designed primarily to meet the demand of steel mills, metallurgical works and similar industries, for a rugged and fully automatic recording optical pyrometer. In its physical construction the equipment has been built to withstand the most severe industrial hazards, but, although of sturdy construction, it is as accurate and fast in operation as a laboratory instrument. Its speed of operation makes the optimatic system ideal for measuring the temperatures of moving bodies. Thus, in a rolling mill, an installation can be used to give an accurate record of the temperature distribution in each slab as it passes any desired point. On the other hand, for stationary bodies such as materials in processing furnaces and certain foundry work, it will produce complete temperature records during the time the objects are viewed.

In use this system comprises three separate units: (1) The optimatic, shown in the accompanying illustration, which is mounted several feet from the hot object. The sighting tube of this unit is " aimed " directly at the object, or the path along which the object moves. The temperature of the hot object causes an electrical reaction in the optimatic which is transmitted to the measuring instruments. (2) The power supply unit provides the electrical excitation for the entire system. (3) The instruments, either for indicating or recording the temperature directly in degrees, can be mounted at any desired location. These are wired to the optimatic and measure electrically the variations in temperature of the hot object. Readings are directly in degrees of temperature.

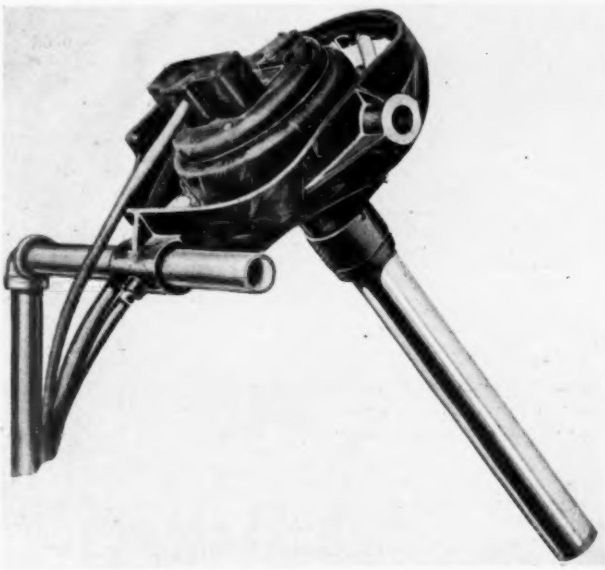
Principle of Operation

The operation of this system is based on the fact that the electrical resistance of a photocell varies with the intensity of light to which the tube is exposed. Also, that the intensity of light given off by a hot body is dependent upon the temperature of that object. Two photocells are employed, each connected into a bridge circuit. One of the cells is exposed to illumination from the hot object, while the other is subjected to light from a balancing carbon filament lamp. For the galvanometer usually found in bridge circuits, an amplifying tube is substituted. As the brilliancy of the hot body varies, the resistance of the photocell exposed to this illumination will change, thus altering the current in the plate circuit of the amplifying tube. This increases or decreases instantaneously the current to the lamp which illuminates the second photocell bringing it immediately into equilibrium with the tube exposed to the hot body. The lamp current also passes through the instrument galvanometers, the deflections of which are calibrated in terms of temperature.

In operation the optimatic unit is " aimed " at the hot target. The intensity of light given off by this hot object causes an electrical change in the optimatic circuit which is amplified and measured directly in degrees temperature. The use of a second photocell, which is indirectly controlled by the changes on the first photocell, gives the system an important factor of stability. Because of this feature, the accuracy of temperature measurement is unaffected by voltage fluctuations in the factory supply. Likewise, the normal variations in the characteristics of the photocells, during continued service, cause no error in the temperature measurements.

Constructional Features

All equipment pertaining to the optimatic system has been designed and constructed with special regard to the practical requirements of industry. Ruggedness, accuracy, flexibility and constancy of calibration have been given foremost consideration. The optimatic includes the sighting tube and a rugged aluminium housing that protects the photocells and the carbon filament lamp.



The Optimatic which is mounted several feet from the hot object.

The sighting tube is an internally baffled duralumin tube that limits the field of view for correct sighting. It protects the lens from dirt and mechanical injury. The maximum distance away from the target that this tube can be placed, is roughly equal in feet to the smallest dimension in inches of the object to be viewed.

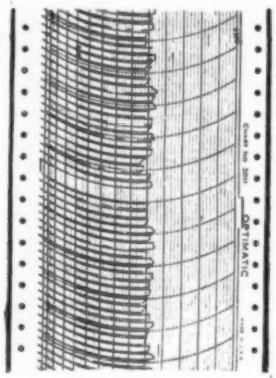
The two photocells and the carbon filament lamp are housed in a moisture-proof aluminium casting provided with a water jacket. This cooling system is used when the optimatic is subjected to high ambient temperatures. The lens and adjustable apertures are also contained in this housing. By means of a finder in the back plate, the unit can be correctly sighted on the target when first mounted. A reflecting glass used in connection with the finder, also serves as a filter for most light rays other than red. This minimizes any danger of small errors in temperature measurements due to the presence of foreign gases or vapours. To prevent vibrational disturbances, the optimatic is suspended by springs from a substantial ring support. This ring is designed to accommodate pipe or flat mounting at any desired angle.

The Power Supply Unit

As its name implies, the power supply unit is the power centre of the system. It is a compact unit and contains the rectifying and amplifying equipment necessary for the operation of the system. It may be mounted in any convenient location. Electrical connections are made from this unit to the factory A.C. supply, the optimatic and the instruments.

The Instruments

Due to the nature of the system, any number of recording or indicating instruments can be used. These may be added or changed at will, as no recalibration or other adjustments are necessary. In addition, they may be mounted at any desired distance from the optimatic.



Typical chart record of a Brown Optimatic System installed in a roughing mill.

The recorder is well constructed for industrial use. The large amount of power available in the optimatic circuit permits the use of a very rugged galvanometer element. This assures quick and positive action of the pen on the chart. The chart can be driven by a handwound clock or by an electric motor. A range of chart speeds ample to meet any practical requirements are available. By means of a quick trip relay the chart speed can be increased automatically from inches per hour to inches per min. the instant a hot object appears before the optimatic. As soon as the object passes from view, the chart resumes its slower speed. This feature permits the instrument to give a greatly extended view of the actual temperature measurements taken from the hot target. By slowing down the chart speed when no temperatures are being measured, the unimportant recordings on the chart are greatly reduced, thereby giving a condensed picture which is handier to use for purposes of comparison. A second pen element can be furnished on the recorder when desired to register automatically definite time intervals during the movement of the chart. This feature permits an accurate check on the rate of production, and provides a valuable record for time study. The indicator is an open-faced instrument that gives instantaneous readings of the temperatures measured. Like the recorder, it is operated by a heavy galvanometer element suited to severe industrial use.

The standard range of both the indicator and the recorder is 1,200–2,500° F., or 650–1,370° C. Other temperature ranges are, of course, available. A calibration unit is included with the optimatic installation. Where several optimatic systems are installed in the same plant, only one calibration unit is necessary. It is built in a portable case and is used to check the optimatic. The only adjustment necessary on the optimatic when being calibrated is a screw adjustment regulating the photocell apertures. A moisture-proof selector switch is available for use where it is desired to operate one set of instruments from several optimatics.

The optimatic system is ideally suited to industrial processes where it is desired to measure or record automatically the temperature of hot objects. These materials may be in motion as in a rolling mill, or they may be at rest, as in a processing furnace. By the use of several sighting units, the temperature variations of a hot target may be recorded as it passes through a series of processes or stages of rolling. Such applications are of particular interest to steel mills.

This system provides a valuable instrument for metallurgical works, and similar industries, where a knowledge of temperature change is an important factor in the manufacturing processes. The complete records, which it secures, offer an invaluable means of assuring consistent temperatures in any process where quality of the finished products depends on the maintenace of temperature during manufacture.

For example, some of the advantages of this system in a hot strip rolling mill, are : It enables the various slab reheating furnaces to be kept at the same temperature. as it detects the slightest unevenness in heating (even skid marks) during the initial stage of rolling, thus it becomes a guide for the uniform distribution of heat from skid to skid or side to side of the furnaces ; it settles controversies between heater and rolling-mill operators, because the record is definite proof of the source of trouble ; by its use the best temperature for the removal of scale, cleaning and finishing of a sheet can be determined and maintained ; from an analysis of the records the best rolling temperatures for different gauges, sizes, etc., can be determined, and duplicated on subsequent runs ; it reduces the number of rejects by revealing faulty processing in the early stages and thus contributes, in no small degree, to the reduction of manufacturing costs ; and it makes possible a permanent temperature record of the mill output, which is particularly valuable for alloy steels and for special orders.

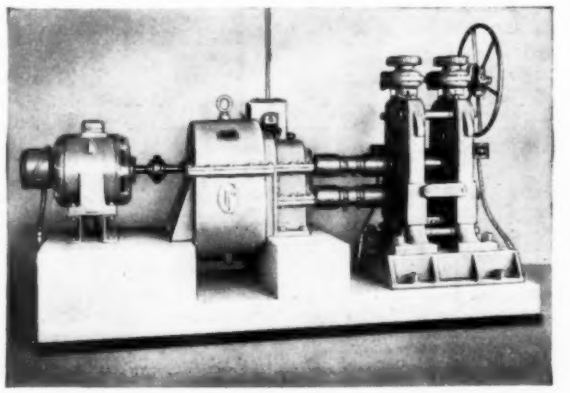
Rolling Mills for Metallurgical Research

IN manufacturing electric lamps, radio valves, and kindred products, the choice and manufacture of raw materials are as important as their subsequent treatment and assembly. For the development and production of the special metals and alloys needed specialised equipment is required, and a large section of the G.E.C. Lamp Works at Wembley is set aside as an alloys factory for this work. Close contact is maintained with the metallurgical department of the adjacent research laboratories of the Company, where the experimental and preliminary development is carried out.

The equipment of the alloy factory includes a 30-k.w. valve-operated high-frequency furnace capable of melting up to 30 lb. of metal per charge at temperatures up to 2,500° C., various annealing furnaces, power hammers and other metal-working plant. Recently three small rolling mills have been installed, and these are to be supplemented by a high-pressure mill of the cluster type, thus completing a modern and comprehensive plant for alloy production.

The three rolling mills at present installed are all of the two-high type with 8-in. diameter rolls. They comprise an 8 × 6-in. unit for rolling cold strip (Fig. 1), an 8 × 12-in. unit for hot sheet (Fig. 2), and an 8 × 12-in. and 8 × 24-in. two-stand unit for rods (Fig. 3). The strip mill will roll

Fig. 1.—Two-high cold strip mill.



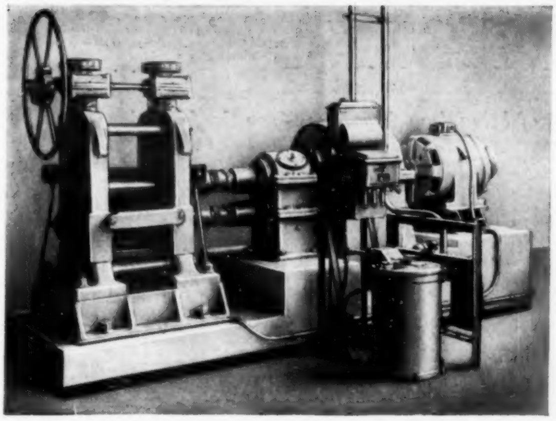


Fig. 2.—Two-high hot sheet mill.

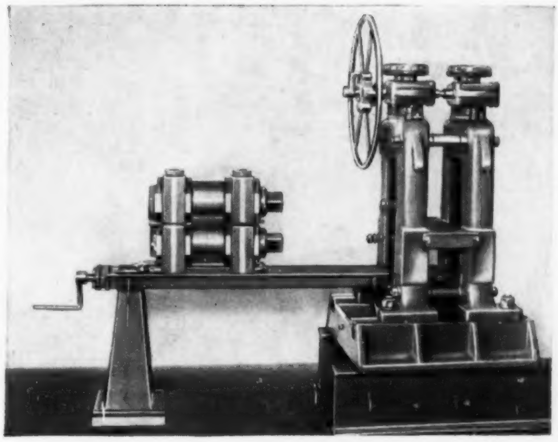


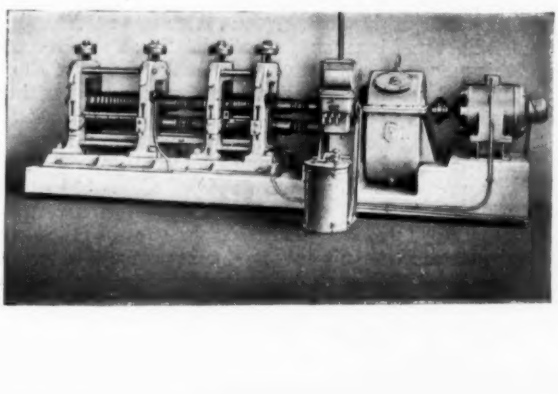
Fig. 4.—Roll-changing device.

material up to 5 in. wide to fine gauges. The rolls are made of special steel having a hardness of 95 scleroscope. Provision is made for fitting a coiling device against the mill housings to receive the rolled strip. In the hot-sheet mill and the rod mill, chilled cast-iron rolls are employed. The former is used for rolling sheet up to 10 in. wide and from ½–0·012 in. thick, and the latter for the hot rolling of special alloy bars down from 1½ in. square to ¼ in. diameter.

The construction of all three mills is generally similar, and the bearings and fittings are interchangeable and made to limit gauge. The rolls are carried by Timken tapered roller bearings of the double row type with a normal load capacity of 70,000 lb. separating force between the rolls. The bearings are arranged to allow a very rapid removal of the rolls from the roll necks without dismantling the covers or oil sealing arrangements. It is only necessary to remove the screws securing the end collars to the roll neck, when the bearing block, complete with roller races, seal rings, and contained lubricant, can be slid off the neck. For roll changing, portable slide rails and a supporting stool with a sliding draw head operated by a screw and crank handle are provided, and each mill stand is fitted with corresponding slide rails set between the housing. These in conjunction with the portable rails form continuous tracks along which slides the pair of rolls with bearings. When in the working position the rolling pressure is taken by wedge blocks beneath the lower bearings; these blocks are arranged to lift the bearings a fraction of an inch above the slide rails. The roll-changing device is seen in use in Fig. 4.

In all cases each roll is driven through a helical tooth pinion (in an integral housing) and straight line spur gearing by G.E.C. slipring induction motors, one of 10 h.p. and two of 25 h.p. The opening between the rolls is adjusted by screw-down gear, machine-divided dials on the screw heads indicating the amount of the opening and the gauge of the product. On the cold-strip mill and the hot-sheet mill the pressure screws are operated by an enclosed worm-and-gear which runs in oil and gives sufficient purchase for the maximum squeezing force on the metal between the rolls to be applied by a handwheel. The latter can be moved laterally so as to act on either or both of the screws through dogs on the worm shaft. In the case of the rod mill the screw-down adjustment is effected by a simple capstan and detachable bar. These three mills were manufactured at the Fraser and Chalmers Engineering Works.

Fig. 3.—Two-high two-stand rod mill.



As an example of the processes carried out by the plant described, molybdenum sheet is produced from pressed-powder bars, which, after sintering are first hot-rolled and then cold-rolled down to 0·22 mm. thick. Thinner material down to foil of 0·01 mm. thick is at present rolled in a small cluster mill.

Tungsten sheet can be made by a similar process. Materials with lower melting points (such as various alloys of molybdenum, tungsten, nickel and iron) are first melted —usually in hydrogen—in the high-frequency furnace and cast into ingots up to 1½ in. square or round. When sheet or strip is required these ingots are first broken down by hot rolling or forging and then cold rolled with intermediate annealings as required. If wire is required the ingots are hot- or cold-rolled in the rod mill down to ¼ in. round or square section, the passes having been designed to give the very gradual reduction necessary for working these alloys; the bars then pass to the swaging machines and drawing benches, where they are worked down, hot or cold, to the required diameter.

Testing Metals by Sound Waves

A defectoscope for the testing of metal up to one metre in thickness has been invented by Professor S. Y. Sokolov. With the aid of the instrument it will be possible to determine the quality of metal with absolute precision before it has been put to use. The appliance is based on the ability of sound to pass through metal. In a metallic or liquid medium, ultra-sound waves are carried forward in the form of narrow bunches. If a crack, an airhole or some other defect occurs in the path of the ultra-sound ray, the ray is deflected and does not pass through the defect. This property was utilised by Professor Sokolov in his new defectoscope, by means of which it is possible to irradiate steel, lead, gold and other metals in block form or as manufactured articles. Consisting of a high-frequency lamp generator, a quartz anode, a quartz cathode and a receiver, the new instrument is convenient and portable.

In addition to the order for coke-ovens recently placed by Messrs. Richard Thomas and Co., Ltd., the Nunnery Colliery Co. have also placed an order with the Woodall-Duckham Co.; it will comprise a battery of 22 W-D. Becker coke-ovens to be underfired by coke-oven gas. The daily capacity of these ovens will be 330 tons of coal.

DROP FORGING

The uniform working of metals and alloys capable of being drop forged results in the formation of structures possessing superior mechanical properties. When properly applied mechanical work multiplies the strength of the material due to refinement in the crystalline structure and the development of directional properties or grain. The subject was discussed recently by Mr. P. Rowley before the Staffordshire Iron and Steel Institute, an abstract of which is given in this article.

A DROP forging is formed between dies by the flow of hot-plastic metal. Its production involves a change of both the form and the section of the material; in this respect it differs from a stamping, in which the form only is changed, the original section of the material usually remaining unaltered. The work is done by means of a drop-forging hammer, which comprises a tup, capable of falling freely under the action of gravity, and a base block. The die blocks, in which are sunk impressions of the shape of the parts to be produced, are in two parts, one fixed to the tup and the other to the base block. Guide rods direct the fall of the tup, and means for adjusting the register of the two die blocks are provided. The double-acting steam hammer, modified to permit greater control over the movement of the tup has become a serious competitor to the other types of hammer. The extra velocity imparted to the tup by the steam pressure, gives a very sharp blow, and recently, considerable improvements in design have been made in which the piston, piston rod and tup are incorporated in one casting.

When dies are sunk for a new pattern there are two essential points to be remembered—namely, there must be a taper or "draft" towards the face of the die so that the forging may leave the impression. This taper may vary from three degrees up to as much as 11° according to the shape of the impression, also there must be no re-entrant angles or cores. The design is marked out on the faces of the dies, and machining is carried out working to templates for the various sections of the pattern. The finish is usually carried out by hand and demands highly skilled workmanship. Die blocks have to withstand very heavy stresses, and they are therefore of substantial size.

The production of a drop forging is brought about by the impact of the top die on the plastic metal which is placed over the impression in the bottom die. The first stress in the die block is due to compression over the area of contact. In addition when the hammer falls, striking the steel between the dies, the central portion of the top die, after causing a certain amount of deformation of the steel is stopped dead for a fractional space of time. The sides of the die, beyond the material being forged, meet with no resistance except the internal resistance of the block itself and they therefore attempt to continue in motion. The result is that pivoting from the edges of the keyways, the outer portions of the block, will whip or bend. The stresses thus set up can be of considerable magnitude, especially if the corners of the keyway are not well radiussed.

To ensure a satisfactory life, a die block must fulfil the following requirements: It must be sound and free from internal defects, capable of resisting deformation and erosion, possess a high impact figure to resist fracture by shock, and the grain flow of the forging from which the die is made should be arranged to the best advantage.

Steels for Dies

Until alloy steels came into popular use, all die blocks were made from plain carbon steel, usually with a carbon content of 0·50–0·60%. After exhaustive experiments it was decided to standardise these carbon steels, also 1·0% nickel steels, 0·50% carbon low nickel-chrome steel, and 3·5% nickel-chrome steel for this purpose. The first three of these standards still maintain their popularity. The actual type of steel to be used depends on the size of the block, and on the quantity of forgings to be produced. Where quantities are small the carbon steel block would be most economical, but large quantities warrant the cost of alloy steels which will ensure longer life.

Billet Heating Furnaces

The earlier furnaces used for heating the steel billets were simply modifications of the old blacksmith's hearth. This type was followed by coal-fired furnaces, but fuel oil has largely displaced the solid fuels as a result of its ease of storage and better control of firing. Gas firing has many advantages over the other types, giving a cleaner heat as a result of the better control over the atmosphere in the furnace, its only disadvantage being the high cost. Aluminium alloys require a forging temperature of 400–450° C., whereas steel forging is carried out at a temperature of 1,000–1,200° C. The most popular form of heating for these light alloys is salt baths and automatically-controlled electric furnaces.

In forging, a "use" or rough forging is first prepared by working the material under dummy tools. This is re-heated if necessary and then placed in the dies, forging being carried out until the impressions are filled and the forging is of the required thickness. During this operation a certain amount of surplus metal flows out between the dies, forming a fin or "flash." This is clipped off by a punch having the same internal shape as the forging contour, the punch being made so that it presses on the forging at points where it is least likely to cause distortion. However carefully the tools are made, a certain amount of distortion does occur, and the forgings are again lightly tapped in the die to correct this.

In designing drop forgings, advantage should always be taken of the grain flow of the material. The original ingot from which the billets for forging are rolled, exhibit a dendritic structure, with its primary crystals at right angles to the ingot-mould faces. On rolling down to size, the dendritic structure becomes broken down and drawn out in the direction of rolling, producing a fibre or grain, and there will be a marked difference in the Izod impact value with or against this grain. In drop forging, it is essential that this grain is so arranged that any stresses shall be exerted at right angles to the direction of the grain flow.

Forging Light Alloys

In dealing with light alloys the rate of absorption of heat depends upon the specific heat and the thermal conductivity. The specific heat of duralumin is 0·214, against 0·116 for steel, but the thermal conductivity is 0·5, compared with 0·11 for steel. Duralumin remains bright at the forging temperature, whereas steel scales heavily, reaching a point where it approximates to black-body conditions. Duralumin therefore, does not readily absorb radiant heat and is much slower in heating up than is steel. For this reason it has been found that furnaces of the air-circulating type are much more efficient for the heating of aluminium alloys than those which depend on radiation. At the forging temperature, the aluminium alloys are harder than steel at its forging temperature, rough tests under a press showing a difference of about 33⅓%. The material, therefore, does not flow as readily as steel, and it is necessary to relieve the radius and taper off die impressions much more than would be necessary for steel forgings. The preliminary forging operations in these materials call

for more care than when handling steel. Owing to their greater resistance to flow they are more susceptible to "laps" and "spills" than steel. In spite of these difficulties, however, the drop forger is now called upon to produce components in the aluminium alloys which, a few years ago, would have been considered difficult in steel.

Distortion of Grains by Fatigue and Static Stressing

TWO extensive X-ray investigations of fatigue in metals have recently been carried out independently and concurrently. C. S. Barrett, with the co-operation of the X-ray and Fatigue Committee of the American Society for Testing Materials, conducted a research at the Carnegie Institute of Technology, while at the National Physical Laboratory a study was made by H. J. Gough and W. A. Wood. The two latter investigators concluded that with alternating torsion-fatigue tests, X-ray diffraction patterns are essentially unchanged by stressing in the safe range, but that abruptly, when the stress passes into the unsafe range, the grains break down and the diffraction patterns are altered. Similarly, with alternating direct stress (tension and compression) they also concluded that, if the mean stress is zero, stressing in the safe range causes no damage in structure that influences appreciably the nature of the X-ray spots, while stressing in the unsafe range alters the spots distinctly.

Barrett, studying rotating beam specimens after stressing, concluded that alternating stresses in the safe range below the endurance limit produce changes in the diffraction pattern that are often of considerable prominence. It was inferred from the results obtained that diffraction patterns did not register the damage to the material and did not permit a direct X-ray diagnosis of ultimate failure from fatigue, and that any X-ray test to reveal actual damage in service or to predict probable life of a stressed component of a machine or a structure would be possible only if it were based on a comparison of patterns from the same material stressed under laboratory conditions. It was considered that the practical importance of this point justified additional fatigue experiments and these, which were carried out using a special X-ray technique, which was thought to be particularly useful for the purpose, are described in a recent issue of "Metals and Alloys."[1]

The X-ray method which was used was an oscillating film method, which is considered to be an improvement over the stationary film method in that it replaces the Debye ring with a band of considerable width and thus permits a large number of spots to be registered without overcrowding. It is, in effect, a method by which a series of diffraction rings are laid side by side each being taken with a slightly different position of the specimen. The data from a band of diffraction rings can then be plotted on a stereographic projection to form a "pole figure" showing the "preferred orientation" for a reflecting grain, or a more convenient procedure is the mapping of latitude and longitude lines from the stereographic projection upon the film or upon a chart superimposed on the film. The angular spread of each spot can then be estimated directly by eye. A detailed description is given in the paper of the construction of such charts for interpreting patterns obtained with the X-ray diffraction camera and oscillating film.

The effect on the grains of cold work from fatigue stressing at different stress amplitudes is discussed from the photograms obtained from various materials. A structural silicon steel with an endurance limit of 21 tons per sq. in. and a yield point of 29·8 tons per sq. in. was stressed to approximately 13·4 tons per sq. in., and to 21·4 tons per sq. in. just above the endurance limit, 2 mm. from the fracture, which occurred after 2,987,100 cycles. The latter stress pattern shows every spot to have been distorted to some extent, and a large number have been blurred so much that their overlapping has produced a nearly continuous band. Cold work produced by stressing below the endurance limit is shown in an annealed plain carbon steel containing 0·85% carbon, having an endurance limit, elastic limit, yield point, and ultimate stress of 15·4, 9·4, 16·3 and 38·0 tons per sq. in., respectively. This steel was stressed at 9·4 tons per sq. in. and at 15·0 tons per in. after it withstood 18,000,000 cycles without breaking and gave a stress pattern in which the spots have become blurred or elongated in one or more directions. An even more pronounced example of distortion of grains when stressed in the safe range is shown in the case of annealed commercial aluminium, containing 99·2% aluminium, with a yield point of 1·4 tons per sq. in. and endurance limit of 2·2 tons per sq. in., when stressed at 1·56 and 1·8 tons per sq. in., respectively. Practically 100% of the grains have become distorted in the latter specimen which withstood 505,000,000 cycles without failing.

The effect of static stressing on the grains was determined by pulling a 0·25 in. diam. rod of Armco iron in a tensile machine, and taking the diffraction pattern after elongations of 0·25, 1·8, 3·3, 6·0 and 10·0%, respectively. A progressively increasing spreading of the spots is obtained as the elongation increases and become less dense as a consequence of their covering greater areas on the film, and overlapping with neighbouring spots to build up a nearly continuous background.

X-ray studies of the oscillating film type as well as previously reported film studies, therefore, fail to reveal any difference in the mechanism of deformation of grains, whether the deformation is brought about by fatigue stressing in the safe range or the unsafe range or by static loading. The deformation results in all cases in a rotation of parts of a grain with respect to each other about a single axis or, more generally, about several axes in an approximately random manner. The range of orientation increases with the stress level in fatigue stressing, and with the elongation in the tensile stressing, gradually reaching a state in which there is insufficient material of any given orientation to give a strong X-ray reflection to a limited spot on the film. In view of these results there can be no question but that the X-ray patterns reveal a distortion of the crystal lattice by plastic flow of the metal along slip planes, and that on the average the distortion is practically the same in the case of fatigue as in the static case.

With general agreement that slip frequently occurs in the safe range and may be recognised by numerous methods, it is pertinent to inquire as to the sensitivity by which it is recognised in the X-ray method compared with the other methods, remembering that the principal limitation of the X-ray method is that it is suitable only for annealed materials. While the available data is too meagre for an exact comparison, the impression is obtained that in this class of materials the X-ray method is more sensitive to flow than some other methods and less sensitive than others. In any case the question is not of prime importance in practice, for once it is accepted that the X-ray diffraction is to be correlated with cold work rather than with spreading cracks or other progressive damage, the X-ray test must take its place with all other tests of the same category. With materials that are cold worked appreciable by fatigue at or below the endurance limit, a test based solely on the X-ray would probably be in error on the safe side, underestimating the endurance properties of the material, while in materials where failure can occur with little or no evidence of cold work, the X-ray would tend to overestimate the endurance of the material, just as the other related tests would.

[1] *Metals and Alloys*, 1937. Vol. 8. Pp. 13–21.

Business Notes and News

Davy Brothers Ltd., Sheffield

Mr. J. Malborn, of the United Engineering and Foundry Co., of Pittsburgh, has entered the services of Davy Brothers, Ltd., of Sheffield, in the capacity of outside technical representative, and he will take up his appointment in Davy's London Offices, Steel House, Tothill Street, Westminster, London, S.W. 1, as soon as these offices are available at the end of March. In the meanwhile, Davy's temporary office in London is situated in Shell Mex House, Strand, W.C. 2.

Mr. Malborn, in his capacity as European engineer of the United Engineering and Foundry Co., is one of the leading authorities on the subject of lay-out and general design of modern four-high hot and cold strip mills. The United Engineering and Foundry Co. are at the present time laying out the plant for Richard Thomas and Co., Ltd., a large portion of which is being manufactured by Davy Brothers, Ltd., of Sheffield.

Arc-Welding Competition

To encourage and stimulate scientific interest and scientific study, research and education in respect of the development of the arc welding industry through advance in the knowledge of design and practical application of the arc welding process, a competition is being held under the auspices of the James F. Lincoln Arc Welding Foundation. A total of 446 prizes are offered for papers covering 11 main classifications and 44 sub-classifications. From the 44 sub-classifications, 220 papers will be selected to receive prizes totalling $81,400. The winner of the Grand Prize will receive $13,700.

The competition is open to any one person, or group of two or more persons. Each entrant must have actually participated in work upon which the subject matter of the paper is based. All papers will be treated as confidential until the Jury of Awards considers the identified but unsigned contesting papers. In rating merits of each paper, the Jury of Award will give equal consideration to the following factors :—

1. Proportionate cost saving in percentage of the design described in the paper over previous design and previous method of construction.
2. The gross savings accruing to industry through the general adoption of the design described.
3. Increased service life, efficiency and general economy and social advantage provided to mankind by the design described.

All of these advantages should be clearly stated.

Only papers sent not later than June 1, 1938, and received in Cleveland not later than July 1, 1938, will be accepted. Full information regarding this competition may be obtained from the Secretary, the James F. Lincoln Arc Welding Foundation, P.O. Box 5728, Cleveland, Ohio, U.S.A.

Technical Institutes Co-operate

The Councils of the Iron and Steel Institute and of the Institute of Metals announce that a scheme of co-operation has been effected between the two Institutes. As a first step in this co-operation, members of each Institute can become members of the other without formality other than written application. Such members will pay a combined annual subscription of £5 5s.

Arrangements have also been made whereby present associates of the Iron and Steel Institute, present student members of the Institute of Metals, and new applicants for membership shall be eligible as associates of the Iron and Steel Institute and as student members of the Institute of Metals up to the age of 26, on payment of a joint annual subscription of £2 2s.; between the ages of 26 and 30 such persons will be eligible as associates of the Iron and Steel Institute (annual subscription £1 1s., no entrance fee), and as members of the Institute of Metals (reduced annual subscription £2 12s. 6d., reduced entrance fee £1 1s.).

This scheme for reduced subscriptions is the first step in a more extensive plan of co-operation that is receiving the attention of the two councils. Those wishing to avail themselves of these provisions or desiring further information are requested to communicate either with the secretary of the Iron and Steel Institute, 28, Victoria Street, Westminster, S.W. 1, or with the secretary of the Institute of Metals, 36, Victoria-street, Westminster, S.W. 1.

Bureau of Analysed Samples

The first year's report of the Bureau of Analysed Samples, Ltd., makes interesting reading. It will be remembered that this company took over from Messrs. Ridsdale and Co., on December, 1935, the whole of their stock of British chemical standards and analysed samples for students. The policy of the previous organisation has been carried on under the directorship of Messrs. N. D. Ridsdale, T. G. Elliot, and A. B. Jones. Premises adjoining No. 3, Wilson Street, Middlesbrough, have been equipped for taking special turnings from the standard bars of steel and castings of iron and non-ferrous metals, as shown in the accompanying illustration.

It is noteworthy that the sale of standard samples during the year shows the maximum turnover since the commencement of the movement in 1916. This increase may be regarded as an indication that the reorganisation of the movement is approved of by chemists generally. It has enabled the company to be self-supporting in the first year of its operation. Contact has been made between the directors of the Bureau and the British Standards Institution which may lead to closer co-operation later on. Friendly associations have also been made with the National Bureau of Standards, Washington, D.C., U.S.A.

Showing special lathes fitted with exceptionally slow feeds for producing thin turnings.

The preparation of fresh turnings of standard carbon steels "Hl" and "P," specially for sulphur by the evolution method, have been well received, and the demand for these has steadily increased; the high Ni-Cr-Cu Austenitic Iron "L" was recently standardised and issued to the public; and the following standards are in course of preparation :—High carbon ferro chromium, 204–2; low carbon ferro chromium, 202–2; ferro vanadium, 205–2; 0·5% carbon steel "F"; rapid machining steel "D" (high sulphur and phosphorus); hematite iron "A 3" (renewal of hæmatite iron "A"); Cr-Ni-Mo steel "B"; and bronze "C," 88–10–2, containing 0·5% maximum Pb and about 0·05% P.

Bessemer Gold Medal Awards

The Council of the Iron and Steel Institute announces that Bessemer gold medals for 1937 have been awarded to Colonel N. T. Belaiew, of Paris, and M. Aloyse Meyer, of Luxemburg.

Colonel Belaiew has published a number of papers of outstanding importance on metallurgy. These have dealt mainly with the crystallisation of metals, and, in particular, steel. M. Meyer is head of the Société Anonyme Arbed, the Luxemburg combine, and second largest iron and steel company in Europe.

International Geological Congress

Soviet geologists are busy preparing for the eighteenth International Geological Congress, which is to be opened in Moscow on July 21, 1937, and is to last for ten days. Tours, both prior to and following the Congress, are being planned for the delegates and their families. Two days of the Congress will be spent in Leningrad, where delegates will visit the Geological Institute in that city. Pre-Congress tours include visits to the Karelian A.S.S.R., the Kola Peninsula, the Ukraine, the Caucasus, the Urals, and other places. Tours during August, conducted by Academician I. M. Gubkin, Professors R. L. Samoilovich, and N. M. Federovich, will cover the Soviet oil-fields.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£100 0 0

ANTIMONY.

English	£77 10 0
Chinese	65 16 0
Crude	36 0 0

BRASS.

Solid Drawn Tubes	lb.	13½d.
Brazed Tubes	„	15½d.
Rods Drawn	„	12d.
Wire	„	11⅛d.
*Extruded Brass Bars	„	8½d.

COPPER.

Standard Cash		£77 2 6
Electrolytic		79 0 0
Best Selected		80 7 6
Tough		79 17 6
Sheets		110 2 6
Wire Bars		81 12 6
Ingot Bars		81 12 6
Solid Drawn Tubes	lb.	15¼d.
Brazed Tubes	„	15¼d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0 4 0
‡Ferro Tungsten	„	0 4 1½
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
NOMINAL: 2-4% Carbon, scale 11/- per unit	ton	30 10 0
NOMINAL: 4-6% Carbon, scale 7/- per unit	„	22 7 6
NOMINAL: 6-8% Carbon, scale 7/- per unit	„	21 12 0
NOMINAL: 8-10% Carbon, scale 7/- per unit	„	21 12 0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	„	33 0 0
Guar. max. 1% Carbon, scale 12/6 per unit	„	36 0 0
§Guar. max. 0·5% Carbon, scale 12/6 per unit	„	37 10 0
‡Manganese Metal 97-98% Mn.	lb.	0 1 3
‡Metallic Chromium	„	0 2 5
§ Ferro-Vanadium 25-50%	„	0 12 8
§ Spiegel, 18-20%	ton	8 5 0
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	6 10 0
20/30% basis 25%, scale 3/6 per unit	„	9 0 0
45/50% basis 45%, scale 5/- per unit	„	11 15 0
70/80% basis 75%, scale 7/- per unit	„	16 15 0
90/95% basis 90%, scale 10/- per unit	„	28 17 6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	14 5 0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 4½
Ferro Phosphorus, 20-25%	ton	22 0 0
§Ferro-Molybdenum, Molyte	lb.	0 4 6
§Calcium Molybdate	„	0 4 2

FUELS.

Foundry Coke—		
S. Wales	£1 12 6 to	1 13 0
Scotland	—	1 8 0
Durham	1 5 6 to	1 6 6
Furnace Coke—		
Scotland	—	—
S. Wales	—	1 7 6
Durham	—	1 1 6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	—
*Commercial Ingots	—
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards.. lb.	£0 1 1
*Cored Bars „	0 1 3

MANUFACTURED IRON.

Scotland—	
Crown Bars, Best	£10 10 0
N.E. Coast—	
Rivets	10 10 0
Best Bars	13 0 0
Common Bars	9 5 0
Lancashire—	
Crown Bars	10 10 0
Hoops........£10 10 0 to	12 0 0
Midlands—	
Crown Bars	10 10 0
Marked Bars	13 0 0
Unmarked Bars ...... from	9 7 0
Nut and Bolt Bars .... £8 17 6 to	9 7 6
Gas Strip	11 7 6
S. Yorks—	
Best Bars	10 15 0
Hoops .... from	11 7 6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	10d.
*Cored Bars	„	1/-
†Strip	„	1/3
†Sheet to 10 W.G.	„	1/3½
†Wire	„	1/4⅞
†Rods	„	1/5
†Tubes	„	1/7½
†Castings	„	1/3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—	
Hematite M/Nos.	£4 18 0
Foundry No. 1	4 10 6
„ No. 3	4 8 0
N.E. Coast—	
Hematite No. 1	4 18 0
Foundry No. 1	4 3 6
„ No. 3	4 1 0
„ No. 4	4 0 0
Silicon Iron	—
Forge	4 0 0
Midlands—	
N. Staffs Forge No. 4	4 3 0
„ Foundry No. 3	4 6 0
Northants—	
Foundry No. 1	4 6 6
Forge No. 4	4 0 6
Foundry No. 3	4 3 6
Derbyshire Forge	4 3 0
„ Foundry No. 1	4 9 0
„ Foundry No. 3	4 6 0
West Coast Hematite	5 3 6
East „ „	—

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0.015, of phosphorus 0.025.	
Per English ton	Kr. 160
Billets, single welded, over 0.45 Carbon.	
Per metric ton	Kr. 295-370
Per English ton	£15 10 0/£19 0 0
Wire Rods, over 0.45 Carbon.	
Per metric ton	Kr.345-395
Per English ton	£18 0 0/£20 15 0
Rolled Martin iron, basis price.	
Per metric ton	Kr.255-270
Per English ton	£13 7 6/£14 5 0
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.330
Per English ton	£17 6 0

f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£61 0 0
„ Braziery	57 0 0
„ Wire	—
Brass	36 0 0
Gun Metal	57 0 0
Zinc	20 0 0
Aluminium Cuttings	74 0 0
Lead	28 10 0
Heavy Steel—	
S. Wales	3 10 0
Scotland	3 12 6
Cleveland	3 8 0
Cast Iron—	
Midlands	3 0 0
S. Wales	3 12 0
Cleveland	3 15 0
Steel Turnings—	
Cleveland	2 5 0
Midlands	2 5 0
Cast Iron Borings—	
Cleveland	1 7 6
Scotland	2 2 6

SPELTER.

G.O.B. Official	—
Hard	£36 2 0
English	37 11 0
India	32 1 0
Re-melted	34 6 0

STEEL.

Ship, Bridge, and Tank Plates	
Scotland	£8 15 0
North-East Coast	8 15 0
Midlands	8 17 6
Boiler Plates (Land), Scotland	8 10 0
„ „ (Marine) „	—
„ „ (Land), N.E. Coast	8 10 0
„ „ (Marine) „	8 17 6
Angles, Scotland	8 7 6
„ North-East Coast	8 7 6
„ Midlands	8 7 6
Joists	8 15 0
Heavy Rails	8 10 0
Fishplates	12 10 0
Light Rails ......£8 10 0 to	8 15 0
Sheffield—	
Siemens Acid Billets	9 2 6
Hard Basic ....£6 17 6 to	7 2 6
Medium Basic..£6 12 6 and	7 0 0
Soft Basic	5 10 0
Hoops..........£9 10 0 to	9 15 0
Manchester	
Hoops..........£9 0 0 to	10 0 0
Scotland, Sheets 24 B.G.	10 10 0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	„	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	„	3d.
Under ¼ in. to $\frac{3}{16}$ in.	„	1/-
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅛ in.	„	3d.
„ „ ½ in. × ⅛ in.	„	1/-

TIN.

Standard Cash	£301 0 0
English	301 10 0
Australian	—
Eastern	296 15 0
Tin Plates I.C. 20 × 14 box	21/-

ZINC.

English Sheets	£48 10 0
Rods	50 10 0
Battery Plates	—
Boiler Plates	—

LEAD.

Soft Foreign	£36 0 0
English	38 0 0

*McKechnie Brothers, Ltd. Mar. 10 † C. Clifford & Son, Ltd., Mar. 10. ‡ Murex Limited, Mar. 10.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.
§ Prices ex warehouse, Mar. 10.